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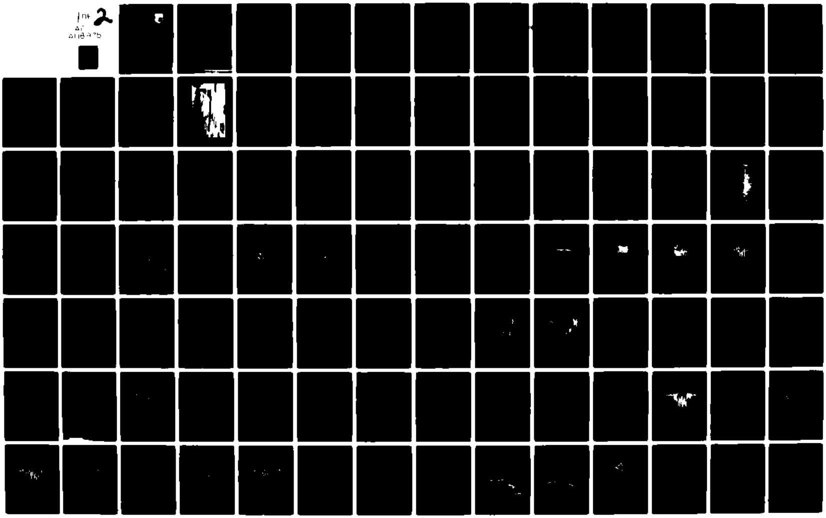

AFWAL-TR-81-1250

PLACES AIRBORNE EXPERIMENT

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May 1982

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AVIONICS LABORATORY
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During December 1980 the Position Location and Communication Effects Simulation (PLACES) Experiment was conducted to investigate the effects of structured ionospheric plasmas on satellite communication and navigation systems. A structured plasma environment was created by a 48-kg barium release from a rocket launched from Eglin AFB Florida. The experiment was directed by the Defense Nuclear Agency and involved ten government, industry and university organizations. Measurements of propagation effects on signals from the LES 8

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20. satellite over the Pacific to a C-135 aircraft operating in the Florida area were conducted. Measurements of the fading depth and fade rate are included in the test results.

FOREWORD

The results contained in this report were obtained during the month of December 1980 at Eglin AFB, FL under work unit 12270313 SATCOM Flight tests.

A major portion of the test results were analyzed by Dr. James Marshall, ESL, Inc. of Sunnyvale, California under DNA contract 001-80-C-0090-project NWET 62710H125AAXHX638-06.

The support of the 4950th TW and a dedicated group of government and contractor engineers in the flight test aircraft made the testing possible.

The encouragement and support of Dow Evelyn of DNA and Dr. Dan McDaniels of SRI were also instrumental in the successful accomplishment of this effort.

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SECTION I
INTRODUCTION

The Position Location and Communications Effects Simulations (PLACES) experiment investigated the effects of structured ionospheric plasmas on satellite communication and navigation systems. A structured plasma environment was created by a barium release from a rocket fired from northern Florida (Eglin AFB). Signal propagation through th cloud was accomplished by transmissions from the LES-8 satellite to th 135-622 aircraft.

The primary purpose of the PLACES experiment was to measu time-of-arrival fluctuations and spread that are associated with radio wave propagation through a strong scatter striated plasma environment. The measurements of time-of-arrival spread and jitter are relevant to the strategic performance of wideband pseudonoise communications and navigation systems including NAVSTAR GPS. The frequency domain manifestation of time-of-arrival spread is fading decorrelation with frequency, and thus, the results of this configuration are also relevant to wideband frequency hopping systems.

The Defense Nuclear Agency conducted a total of four barium releases on Dec. 4, 6, 8, and 12, 1980. These launches occurred near local sunset. The test aircraft flew a pattern under the barium cloud to measure the effects of the striated plasma on the satellite to earth propagation.

SECTION II
TEST ORGANIZATION

The PLACES field program was sponsored by the Defense Nuclear Agency and was planned and carried out by SRI International (McDaniel, 1980). The satellite and beacon experiments were conceived and implemented by ESL, Inc. The program participants and their areas of responsibility are as follows:

- DNA--Program sponsorship and management
- SRI--Test planning and direction, and operation of FPS-85, TV tracking system, inosonde, and magnetometer
- ESL--Satellite and beacon measurements, beacon payloads, and operation of beacon ground stations
- SLA--Rocket operations, payload integration
- Thiokol--Barium payloads
- NRL--Pulsed plasma probes
- AFGL--Mass spectrometer
- TIC--Ground optics
- LASL--Intensified optics
- AFWAL--Aircraft experiment
- ESD--Satellite support
- 4950th TW--Aircraft support

SECTION III

TEST CONCEPT

The PLACES tests consisted of four 48-kg barium releases that were launched during the period 4 to 12 December 1980 (McDaniel, 1980). Associated with the barium events were the launch of in-situ probe rockets, and RF beacon rockets. Event times were selected to optimize the visible window at the time the cloud was most sharply striated. During each of the four barium events, a C-135 aircraft equipped by the Avionics Laboratory made multiple passes through the barium ion cloud shadow, recording signals from a satellite. The geometry of the experiment is depicted in Figure 1. The rocket and aircraft experiments were supported by various groups of instrumentation, to be described later. The test elements of PLACES are as follows:

- 48-kg barium releases (4)
- Rocket-borne beacons (4)
- Rocket-borne probes (2)
- 4950th aircraft C135/662
- FPS-85 radar system
- Beacon receiver stations (2)
- TV tracking stations (2)
- Ground optics (3 sites)
- Intensified optics (1 site)
- Manetimeter/ionosonde
- Range support systems

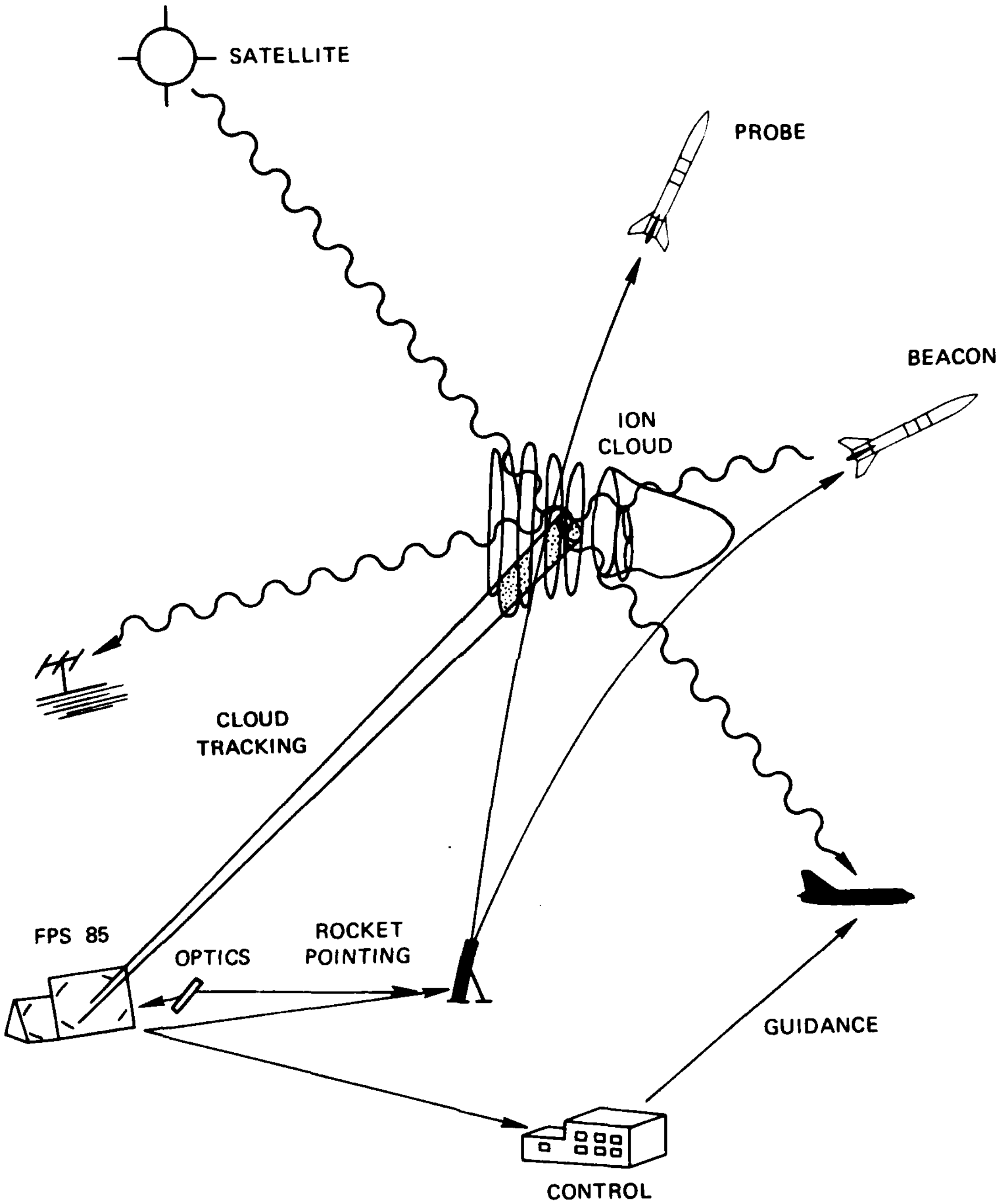

FIGURE 1 PLACES CONCEPT

SECTION IV

TEST CONFIGURATION

The Avionics Laboratory SATCOM flight test aircraft (Figure 2) flew patterns such that UHF (300 MHz) and Ka band (38 GHz) signals were received through the Barium ion cloud. Lincoln Laboratory Experimental Satellite (LES-8) eight was the signal source. The test geometry is depicted in Figure 3.

UHF phase and amplitude were measured, recorded, and transmitted via another satellite (FLTSAT at 23^{o}W) to the Eglin Central Control Facility (CCF), where the data was realtime processed and presented in useful form to the test director.

This report describes the SATCOM aircraft test configurations and shows typical data recorded on the aircraft and the processed data on the ground.

LES-8 UHF DOWNLINK

The prime measurement was a CW downlink at UHF (339.6447266 MHz) from LES-8. This signal was downconverted (ESL Receiver) to a 500 Hz tone using Local Oscillators phase locked to a Rubidium frequency standard. This 500 Hz tone (called the predetected tone or PRE-D) was recorded directly on magnetic tape, along with a 1KHz tone also derived from the Rubidium frequency standard.

The ESL Receiver-Gain was set such that in normal undisturbed reception, the amplitude of the 500Hz PRE-D Signal was equal to the amplitude of the 1KHz reference. Thus any UHF signal fade or enhancement may be determined using the 1KHz tone as an amplitude reference. Similarly, any phase change (after doppler frequency shift is removed) of the 500 Hz PRE-D signal may be determined by using the 1KHz tone as a phase reference.

Figure 2. Test Aircraft

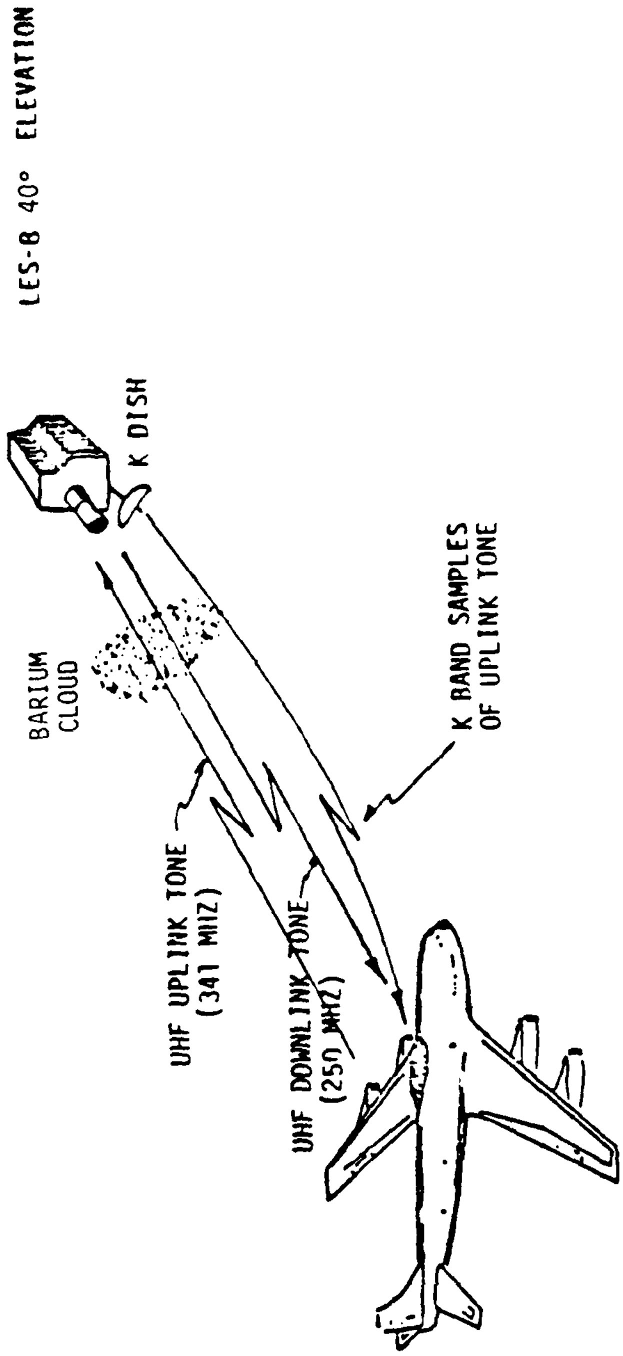

Figure 3. PLACES Aircraft Experiment

LES-8 Ka BAND DOWNLINK

The Doppler frequency shift was removed through use of the Ka band downlink signal. This downlink signal and the UHF downlink signals were phase coherent, through referencing to the same frequency standard within the LES-8 satellite. The Ka band antenna tracked the signal using the ASC-28 auto track receiver phase locked to the Ka band signal and a 20mHz VCO as the tracking mechanism. This VCO output is 20mHz plus or minus the Ka band Doppler frequency shift. The UHF Doppler shift may be scaled from the Ka Doppler shift and utilized as a downlink phase coherent reference to remove Doppler shift of the UHF downlink signal. If the Ka band signal is stable and the ESL receiver Local Oscillator are tunable in sufficiently small steps, all UHF Doppler shift may be removed. Because of the frequency dependence of the barium scintillation, the Ka band signal is not affected by the barium scintillation. The ESL receivers are tunable to within 0.1 Hz. This results in residual Doppler of less than 1Hz. Further processing by ground computer at the CCF was used to remove the small residual Doppler.

LES-8 UPLINK UHF CW

The second UHF signal was an uplink UHF CW (391.9125000 MHz) to LES-8. The signal was Doppler pre-corrected by use of the scaled Ka band Doppler shift. At the satellite the signal was digitized at a 100K bit rate using one bit I, Q samples. The data was used to BPSK modulate the Ka band downlink. The I, Q data was recovered and digital to analog converted into the equivalent I and Q signals as received by LES-8. These reconstructured signals were recorded on magnetic tape. Ideally an undistributed output would be two DC signals. Realistically the signals slowly change phase

at less than 0.1 Hz rate. Uplink power was set to a 3db S+N/N ratio in the satellite.

UHF DATA TRANSFER LINK via FLTSAT

The remaining UHF link transmitted the combined 500 Hz "PRE-D" tone and the 1KHz reference, using narrowband FM without preemphasis, or AGC, to the Central Control Facility (CCF). This data transfer link used 25 KHz of the 500KHz wideband portion of the FLTSAT satellite located at 23°W longitude. This link was at a low evaluation angle (15°-20°), which did not pass through the barium cloud and was therefore stable.

At the CCF, computer processing presented the test director with real time data of the phase and amplitude variations.

DETAILED CONFIGURATION

The aircraft equipment configuration used during the PLACES experiment is shown in Figure 4. Also known in Figure 4 are the track assignments used in recording the data both on the Ampex AR-200 analog tape recorder and on the 8-channel strip chart recorders.

The format shown for the analog tape recorder was essentially the same as that used during the 1977 STRESS Experiment. The 8-channel strip chart recorder format was new and intended to accommodate and display the uplink fading data together with the downlink data. The display of the K-band video spectrum was intended to provide a reference as to the strength of K-band lock and it divides the uplink and downlink data on the chart display. In addition a lock indicator of the K-band receiver was remoted to a marker pen. The log envelope output on the uplink tone processor had

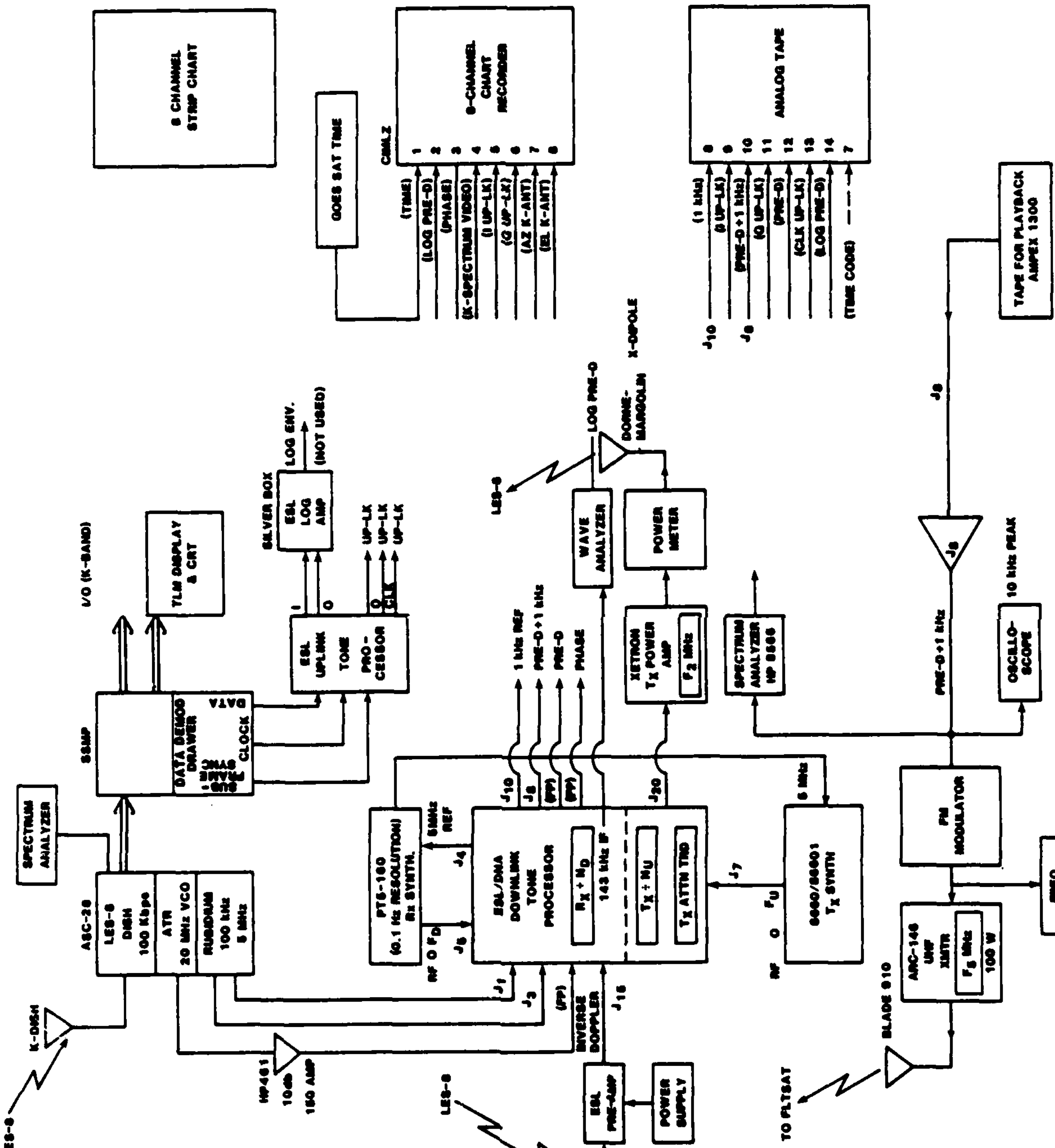

Figure 4. Aircraft Equipment Configuration

degraded to the point where it was believed to be of marginal quality, and thus was not recorded. The aircraft heading data from the INS was recorded on the digital tape recorder. The K-band antenna Azimuth and elevation was displayed on the strip chart and recorded on the analog tape recorder.

The Dorne Margolin antenna was used for the UHF LES-8 uplink. The uplink power was set to a point approximately 6 dB below saturation at the satellite.

The Collins Crossed Dipole was used for receipt of the UHF LES-8 downlink tone.

The downlink tone and a 1 kHz reference tone (PRE-D + 1 kHz) were sent over a 500 kHz channel on the Atlantic FLTSATCOM (23°W) satellite to the CCF. This was the same signal as recorded on Track 10 of the analog recorder. It was FM modulated using a 10 kHz zero to peak frequency deviation under non-fading conditions. Using a 50 kHz IF receive bandwidth at the Eglin ground station, a peak signal enhancement (focus) of approximately 9.5 dB was accommodated without distortion. It was important that an AGC was not used at the modulator otherwise long signal enhancements (focus and defocus) would not be accurately reproduced. A blade antenna on the top side of the aircraft was used for this link together with the ARC-146 transmitter. Approximately 100 watts of the 1 kW available transmitter power was required on the FLTSATCOM link.

The K-band receiver provides the K-band doppler to the downlink tone processor on a 20 MHz VCO output. The K-band receiver also demodulated the I-Q uplink samples sent down on this K-band link. These samples were output to the uplink tone processor along with subframe sync and clock data.

UPLINK TONE POWER SETTING

This operating point was found by measuring the magnitude of the uplink I and Q outputs of the uplink tone processor versus the uplink tone power. The uplink power was then set 6 db below the point at which the output signal power (I^2+Q^2) no longer varies linearly with the uplink tone power. The resulting signal was close to the point at which the signal-to-noise ratio in the satellite 75 kHz IF bandwidth is 0 dB. This was checked by turning the uplink tone on and off and reading the satellite receive signal strength from the LES-8 satellite telemetry display. With the signal on, a S+N/N of 3 dB (S/N = 0 dB) was displayed; with the signal off, 0 to 1 dB was displayed. As the telemetry value has only 1 dB resolution the uplink was varied slightly to confirm the telemetry tracked. The signal-to-noise ratio was approximately measured and sent down over the K-band telemetry link to the command terminal where it was displayed. The calibration procedure described above was followed prior to each release and immediately following the experiment.

LES-8 Satellite Mode Configurations

The mode used on Les-8 for the PLACES experiment is listed in Table 1. The proper pointing of the satellite dish antenna did not vary significantly as a function of time. It was not necessary to repoint the satellite antenna during the experiment.

ESL Rx/Tx Settings

The frequency pairing used during the experiment are listed in Table 2. The corresponding satellite synthesizer octal and decimal codes are listed and could be read on the telemetry panel. The synthesizer settings

TABLE 1

LES-8 SATELLITE CONFIGURATIONS FOR PLACES EXPERIMENT

Configuration	UP & DNLK Tone Date
Satellite	8
Lo Rate Data Source	TLM
Horn Xmit	Off
Dish Xmit	U
UHF Xmit	Synth
Power	6 watts
WOD #	3
DNLK Synth	Stop at 250.326 3916 MHz
UPLK Synth	Resultant 339.644 726 6 MHz
HOP Int.	200 ms
UPLK Ant.	UHF
BB Demod.	Sampler
Data Rate	100 Kbps
XLK Ant.	Dish
Dish Ptg.	(30^{o}N, 85.5^{o}W) (1)

(1)Maintained pointing throughout mission, precise coordinates were provided day of test.

TABLE 2

LES-8 FREQUENCY SELECTION PAIRING FOR UPLINK AND DOWNLINK TONES
USED DURING PLACES

DOWNLINK

K-Band Source	÷N	Freq. (MHz)	Doppler Error (Hz)	Satellite Synth Octal	Satellite Synth Decimal	HP 8660 Synth (Hz)	Freq. Offset Error (Hz)
LES-8 Dish 38.04 GHz	152	250.326 391 6	.08	4650344	1265892	40 184 313	-.35

UPLINK

÷N	Resultant Sat. Freq. (MHz)	Satellite Synth Octal	Satellite Synth Decimal	HP 8660 Synth (Hz)	Transmit Freq. (MHz)	± Doppler Correction (Hz)	Uplink Doppler Error (Hz)	Total Freq. Offset Error (Hz)
112	339.644 726 6	0650345	217317	59 823 297	339.644 726 6	± 453	.002	-.03

(R_x and T_x) for the downlink tone processor are also given. A PTS-160 synthesizer was used which had 0.1 Hz resolution which allowed the Rx offset error to be reduced below the 0.35 Hz.

Due to aging of the satellite oscillators and to frequency setability constraints the optimum settings varied slightly. The preferred setting was the one that results in the least residual total frequency offset error, e.g., on the normal downlink tone the output should be exactly 500 Hz. This offset was nulled using the 0.1 Hz resolution of the PTS-160 frequency synthesizer until the Rx phase detector was close to a straight line on the strip chart. The setting on the uplink tone was checked by noting when the uplink I and Q did not change on the strip chart. These were checked before the aircraft was in flight.

REAL TIME RELAY THROUGH FLTSATCOM

The aircraft fading data was relayed through FLTSATCOM to the B-4 site at Eglin AFB and from there a microwave link to the CCF building for processing as depicted in Figure 5. The signal format that was sent to the CCF was the same downlink format that was recorded on the 662 aircraft. The fading signal "PRE D" was at 500 Hz and was essentially contained within a 10 Hz bandwidth. A 1 kHz reference signal equal in amplitude with the 500 Hz tone under non-fading conditions was sent as a reference to be used by the ground processing software to eliminate any frequency translation errors in the telephone equipment, any slowly varying amplitude and phase variations in the transmission path or on the telephone lines, and any error in the sampling rate of the A/D converter at the ground. In addition the ESL receiver gain was stepped 1 dB up or down so as to match the 1 kHz reference at the beginning of each run.

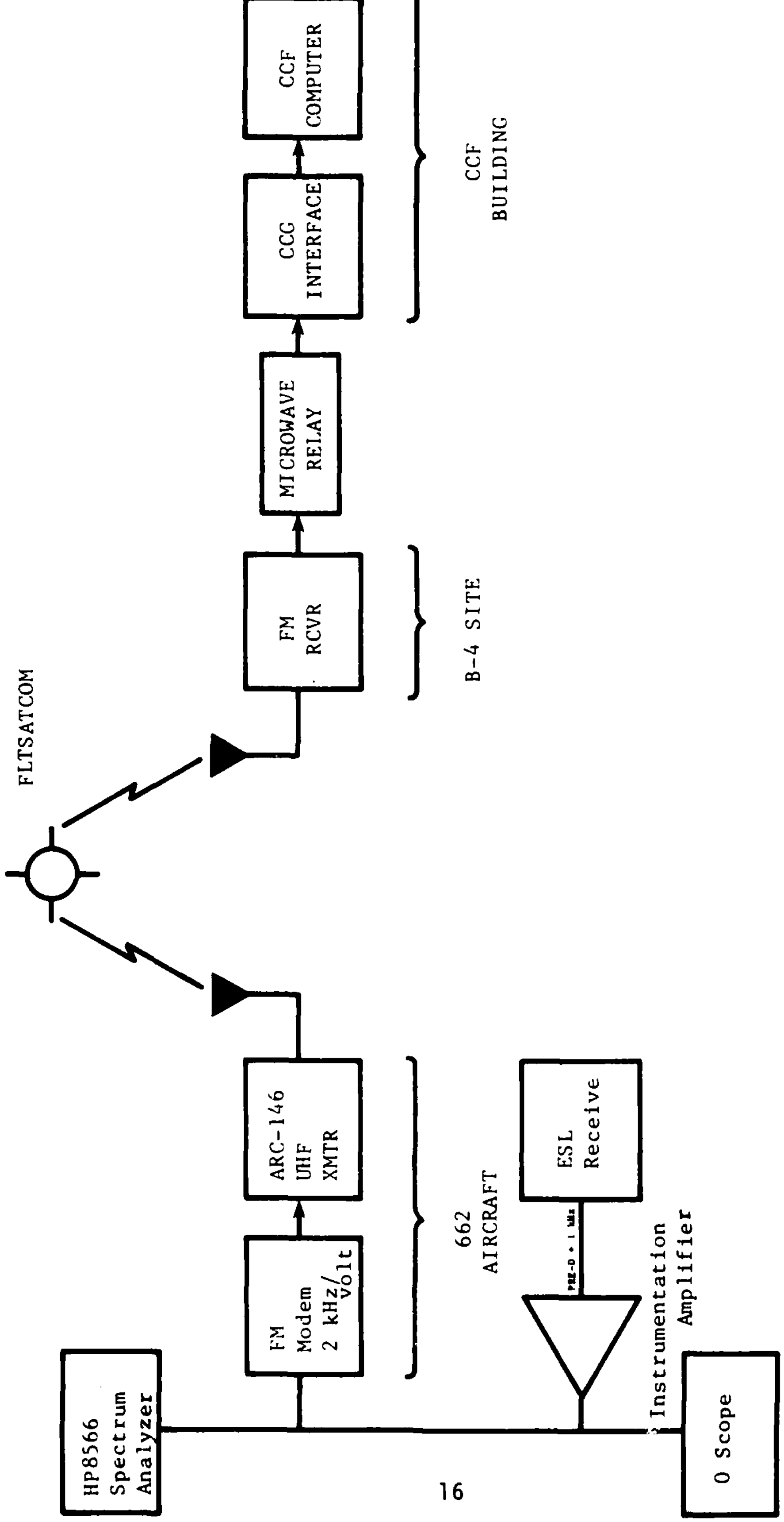

Figure 5. Real Time Data Relay

The 500 kHz wideband transponder of the FLTSATCOM satellite over the Atlantic Ocean at 23^{o}W (Az≈103.8^{o}, El≈14^{o}) was used. Aircraft transmit frequency was 294 mHz.

A link calculation for this channel is provided in Table 3. For transmitt 100 watts of power was used from the aircraft (ARC-146). This produced a 12.9 dB carrier-to-noise ratio at the ground reciever (50kHz.IF). The ground antenna had 10 dBi of gain (circular polarization). At the A/C with a 0 dB antenna (the blade at Sta-910) and a 4 dB noise figure, the FLTSATCOM downlink C/Kt was 45 dB. Frequency deviation by the combined PRE-D (500 Hz) and the 1 kHz reference was 10 kHz peak (20 kHz peak to peak).

No AGC or pre-emphasis was used at the transmitter in order to keep from distorting long signal focus or defocus regions of fading. ESL Receiver gain was set so an input of - 124 dBM gave a PRE-D output equal to the 1 kHz reference tone. This required a peak to peak voltage input to the FM modulator of 10 volt. The HP 8566 analyzer was used to ensure that the unfaded PRE-D signal matched the 1 kHz amplitude. Any receive antennas variation were removed by adjusting the ESL receiver gain.

USING RELAYED DATA FOR AIRCRAFT EXPERIMENT CONTROL AT THE CCF

The key to improved data quality was the improved real time aircraft and cloud tracking displays at the CCF in conjunction with the real time display of fading as seen by the aircraft and sent to the CCF via a FLTSATCOM relay link. Additionally, near real time data processing was used to ensure the highest possible quality of data results from the aircraft positioning.

A display of the aircraft and barium ion cloud shadow positions were used to vector the aircraft through the barium cloud shadow at the

TABLE 3

LINK CALCULATION FOR FLTSAT REAL TIME RELAY -
500 kHz CHANNEL

a/c to Satellite		Comments
XMTR Power	20 dBW	Min. required
Antenna Gain	2 dBi	
EIRP	22 dBW	
Space Loss	173.9	@ 296 MHz @ 14 deg. elevation
Polarization Coupling Loss	0.3 dB	
G/T Satellite	-16.7 dB/°K	
Boltzmans Constant^{-1}(K^{-1})	228.6 dB-°K-Hz/W	
C/kT	59.7 dB-Hz	
Inverse Bandwidth	-57.0 dB-Hz	500 kHz Channel
SNR @ Limiter	2.7 dB	
Limiter Gain	~2.5 dB	
SNR after Limiter	5.2 dB	

Satellite to B4 Site		
EIRP	25.6 dBW	RHCP
Power Sharing Loss	~1.1 dB	No other users
Space Loss	172.9 dB	@ 262 MHz
Polarization Coupling Loss	0.3 dB	
Antenna Gain	10.0 dBi	(13 dBi Linear)
Received Power	-138.7 dBW	
kT	-198.6 dBW/Hz	1000°K Noise Temp
C/kT	59.9 dB-Hz	
Inverse Bandwidth	-47.0 dB-Hz	50 kHz
CNR	12.9 dB	(~6 dB Margin)
FM Improvement	35.7 dB	7 kHz Peak Frequency Dev.
SNR in 1 kHz	48.6 dB	$=3/2\ (f_d/f_m)^2\ (B_{IF}/f_m)$ CNR

NOTE:

8 dB CNR gives 31.5 dB SNR
7 dB CNR gives 26.1 dB SNR
6 dB CNR gives 21.6 dB SNR

proper azimuth. The cloud shadow presented a moving target to the aircraft controller. The aircraft was positioned to fly through the shadow of LES-8 cast by the barium cloud perpendicular to the projection of the earth's magnetic field lines. This geometry swept the striated portion of the barium cloud in the minimum time, and provided an easy to interpret propagation geometry.

Normally the cloud tracking data (cloud projection point, its drift velocity vector, and field line projection cross) was supplied to the CCF through a real time link from the AN/FPS-85 radar.

However an ability to compute the current position of the cloud from past data was used when the radar lost track of the barium ion cloud. This problem had occurred several times during the PLACES experiment.

In actual fact, the real time fading display along with the aircraft location data proved adequate for several hours during GAIL and JAN. A real time display showed the fading as received on the aircraft and display of the aircraft track with respect to the cloud center. These displays provided a real time history of fading as a function of the aircraft position relative to the radar cloud track point and allowed a more precise control of the aircraft.

UHF DOWNLINK CALCULATIONS

The link calculation for the downlink UHF tone is listed in Table 4. The predicted received carrier power-to-noise power density ratio (C/KT) was 46.1 dB-Hz. The value measured during experiment was 51 dB/Hz. The greater value is believed due to higher than expected aircraft antenna gain.

TABLE 4

LINK CALCULATION DOWNLINK TONE TO AIRCRAFT

XMTR Power	37.8 dBm	6W
Antenna Gain	9 dB	
EIRP	46.8 dBm	
Space Loss	171.9 dB	@ 245 MHz El=35° R=38,193 km h_s=35,800
Polarization Loss	0.4 dB	3 dB to 3 dB El=50° R=37,091 SL=171.6 dB
Receiver Gain	3 dBi	
Receiver Power	-122.5 dBm	
Noise Density	-168.6 dBm/Hz	T=1000 degrees
C/kT	46.1 dB-Hz	
Noise Power	-148.6 dBm	100 Hz BW - real time a/c indicator?
A/C Strip Chart SNR	26 dB	Real time on a/c
Noise Power	-156.8 dBm	15 Hz BW Real time @ CCF
SNR	34.2 dB	CCF displays

The real time fading indicator on the aircraft used the log output of an HP 8566 spectrum analyzer. The detection bandwidth was 100 Hz giving an unfaded signal-to-noise ratio of 30 dB on the real time strip-chart.

LES-8 UHF UPLINK CALCULATION

A link calculation for the uplink tone is listed in Table 5. The uplink power level was set to approximately 0dB SNR at the satellite. The corresponding effective C/kT was 42.8 dB-Hz. The uplink power was set by noting at what uplink power the satellite output signal on the I, Q strip chart to compress. The uplink power was then backed off 7dB. This resulted in a C/kT of approximately 38 dB-Hz at the satellite.

The baseband converter used 256 bit averaging windows on the I and Q, which corresponds to approximately a 360 Hz bandwidth. After D to A conversion these signals were recorded on the strip charts. Calibration was made by varying the UPLINK power.

LES-8 K-BAND DOWNLINK CALCULATIONS

An approximate link calculation for the K-band downlink to the 662 aircraft is listed in Table 6. This calculation indicates there was 4 dB of margin at the 100 Kbps data rate. Actual C/kT at K-band was 61 dB/Hz compared to the calculated 60.3 dB/Hz.

DOWNLINK TONE PROCESSING

The measurement of phase data on the downlink tone was made possible by phase referencing the UHF tone to signals divided down from the LES-8 100 Kbps K-band doppler signals.

Recordings of the downconverted doppler corrected signal was the real time outputs of each flight test. The UHF signal was downconverted to a

TABLE 5

UHF CALCULATION UPLINK TONE AIRCRAFT-To-SATELLITE

XMTR Power	44.4 dBm	(27.5W) Adj. for 0 dB SNR (100W max)
Antenna Gain	2 dBi	±2 dB
EIRP	46.4 dBm	
Space Loss	175.9 dB	@ 388.4 MHz, 35°El, R=38,193
Polarization Loss	0.5 dB	±0.5 dB 5 dB to 3 dB
Receiver Gain	10 dBi	±1 dB
Incident Power	-120.0 dB	±2.3 dB
Noise Density	-167.8 dBm/Hz	
C/kT	47.8 dB-Hz	
Noise Power	-120 dBm	±1 dB in 60 kHz
SNR	0 dB	±2.5 dB at input to limiter
$SNR_{AL/samp}$	-5 dB	Simulation results (after limiter and Sampler)
$C/kT_{AL/samp}$	42.8 dB	
SNR	17.2 dB	in 256 bit window (~360 Hz BW) real time
SNR	23.2 dB	in 1024 bit window (~90 Hz BW) post process

TABLE 6

K-BAND DOWNLINK CALCULATION

XMTR Power	26.2 dBm	(.4 watt)
Antenna Gain	42.6 dBi	(3' dish)
EIRP	68.8 dBm	
Space Loss	216.0 dB	@ 38 GHz
Receiver Ant. Gain	47.0 dBi	
Received Power	-100.2 dBm	
Noise Power Density	-164.5 dBm/Hz	9.5 dB noise figure
C/kT	64.3 dB-Hz	
Loop SNR	50.3 dB	25 Hz BW
E_b/N_o Required	10.3 dB	10^{-5} BER DPSK
R	50 dB	100 Kbps
C/kT required	60.3 dB/Hz	
Margin	4.0 dB	

frequency that was nominally 500 Hz. Recorded on the same FM tape track was a 1 kHz reference tone. The same 1 kHz reference tone was also recorded alone on a separate tape track. Analog tape data was processed after the test in the ESL Tape Center. The analog 500 Hz plus 1 kHz track was 8-bit digitized at a 4K sample per second rate and stored on digital tape for subsequent computer processing. The nominal level of the 500 Hz signal on the tape was equal to the 1 kHz reference signal level during nonfading signal conditions. An IBM 4341 software demodulator program was used to output the amplitude and phase of the envelope of the 500 Hz data. Plots of the amplitude and phase were generated by a subsequent software routine and could be back-propagated.

UPLINK TONE PROCESSING AT SATELLITE, AIRCRAFT, AND GROUND

Obtaining data from the aircraft uplink to the LES-8 involved a significant amount of data processing. The aircraft transmits signals that were doppler precorrected.

The systems on the satellites which process the UHF uplink tone transmitted from the aircraft were as follows. The signal received at the satellite was amplified by the UHF FRONT END. The DOWNCONVERTER downconverted the signal from UHF to IF. The "SAMPLES" BASEBAND CONVERTER hard limited the signal, downconverted it to baseband, and converted the coherent and quadrature outputs of the baseband downconversions to digital data streams using 1-bit sampling (hard quantizing). The SIGNAL PROCESSOR formated the sample data stream together with synchronization and telemetry data. The formatted data was DPSK modulated and sent via K-band back down the aircraft. The K-dish system was used to transmit the high data rate required.

The DOWNCONVERTER acted as simple mixer and merely translated the uplink UHF signal down in frequency. The actual DOWNCONVERTER on the satellite was somewhat more complex that its name would imply, but the effective translation was the same. The first BPF of the BASEBAND CONVERTER filtered the translated signal to a bandwidth of 75 kHz. The hard-limiter system (HL/FIL) hard limited the received signal and filtered out the higher frequency components from the hard-limiter output. The signal was then mixed down to baseband with an I-Q mixer. The I and Q signals were low-pass filtered to a cutoff frequency of 35 kHz before they were 1-bit sampled each at a 50 kilobit per second rate.

The SIGNAL PROCESSOR used a 50-bit frame format into which the I and Q samples were put. The first bit position was for the SYNC bit which was always a "1" and was conventionally used by the reportback and cross-link demodulators to achieve frame synchronization. The next bit position was dedicated to bits of the forward message. The third and fourth bit positions were dedicated to telemetry information and the fifth through fiftieth bit positions carried the I and Q samples alternating between I and Q. In the formatting process, some of the I and Q samples from the BASEBAND CONVERTER were dropped in order to accommodate the bits in the 1 through 4 bit positions. Two out of 25 bits were lost from both the I and Q channels in this manner. The effective I and Q data rates were, as a consequence, each decreased to 46 kilobits per second.

This transmitted data stream was demodulated and processed at the aircraft for eventual recovery of the inphase and quadrature signals. The technique used in recovering the signals from the hard quantized

data relied on the fact that the diffracted field received at the satellite was of a low power, comparable to the received noise power. As each bit in the sample stream was a measure of whether or not the signal plus noise voltage at some instant of time was greater than 0, the summation of a number of these bits over an interval represented a probability estimate of this voltage being greater than 0 within that interval. It was this computed probability that will be used to recover the original I and Q signals. In the aircraft the demodulated data stream was sorted and serially fed into a pair of 256-bit shift registers and UP/DOWN counters. By comparing the delayed bit from the shift register with a current bit from the I/Q sort, the counters generated a running sum of the number of 1's in a 256-bit window. The counter output was then converted (D-A) once every 2.78 milliseconds to an analog voltage, was displayed on strip chart, and FM recorded an analog tape along with time frame data. Computer implemented processing which followed this step treats the recorded data as probability estimates made over the window time frame. At the incoming data rate of 46K bits per second this 256-bit window derived its probability estimate from a 5.56 milliseconds window.

SECTION V

TEST RESULTS

INTRODUCTION

The aircraft experiment employed LES-8 throughout the test. The uplink and downlink tone processing equipment built by ESL under the STRESS program performed reliably. There was no apparent degradation over the past 3 years in the overall signal quality. In fact, 2 or 3 dB of SNR improvement appears to have been realized, possibly through a combination of more favorable geometry and hardware/antenna changes on the aircraft. A quick look at the downlink C/kT indicated approximately 51 dB-Hz compared to 46 to 47 dB-Hz measured during STRESS.

The data recorded in the aircraft is summarized in Table 7. Both uplink and downlink data were available except during periods when K-band phase lock was lost. Without K-lock the uplink tone data was lost. A detailed summary for each release for each pass is provided in the subsequent sections. The real time processing software quickly corrected by the highly efficient CCF programming staff. Loss of K-lock would result in loss of phase lock in the real time processing software, but again this only presented minor difficulties. The greatest difficulties were encountered with the FPS-85 radar tracking data. Only during event IRIS was useful cloud data obtained consistently for positioning the aircraft. Without the real time relay link through the FLTSATCOM and the associated aircraft position displays it would not have been possible to position the aircraft and obtain fading data on the other three events. The quality of the real time fading display is illustrated in Figure 6. The phase data was enhanced through proper windowing and processing of the data as recorded on the aircraft.

TABLE 7

A/C DATA SUMMARY

RELEASE	RELEASE TIME	RELEASE ALTITUDE	RELEASE LOCATION	NO. OF PASSES	DATA PERIOD
GAIL 12/4/80	2307:36Z	178.1 km	~29.37°, ~87.37°	32	2307:10 --- 0148 0136 LAST STRONG FADING (R+2:29)
HOPE 12/6/80	2307:37Z	179.4 km	~29.25°, ~87.0°	33	2307:40 --- 0206 0113 LAST STRONG FADING (R+2:06)
IRIS 12/8/80	2313:07Z	179.6 km	28.799°, 87.166°	31	2329 --- 0205 0150 LAST FADING DATA (R+2:37)
JAN 12/12/80	2313:42Z	184.3 km	29.166°, 86.993°	35	2314:06 --- 0200 0157 LAST STRONG FADING (R+2:43)

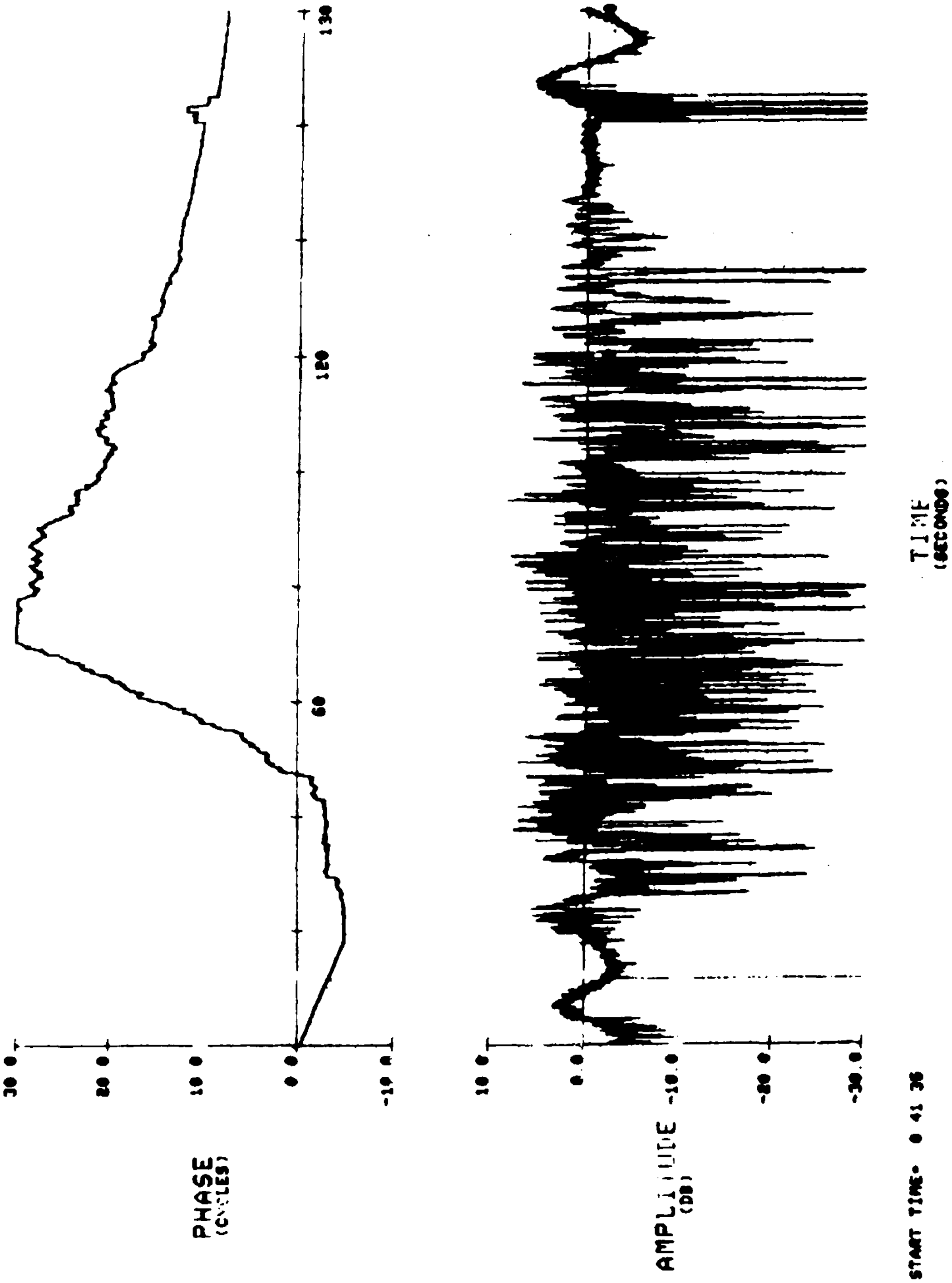

Figure 6. Real Time Fading Display for Event JAN at R+1^{h}28^{m}

The following sections describe the aircraft experiment results for the four PLACES barium releases, GAIL, HOPE, IRIS, and JAN. The discussion includes the cloud tracking data, the aircraft location data correlated with periods of intense fading, and samples of the uplink and downlink test results.

TEST RESULTS FOR GAIL

The barium cloud for the first experiment, GAIL, was released on 4 December 1980 at 23:07:36Z. It was released at an altitude of 178.1 kilometers approximately 87.37°W, 29.37°N. The projection at release of this cloud from the LES-8 satellite down to the 10.668 kilometer aircraft altitude is 86°14'36"W, 31°25'43"N. This is slightly southwest of the planned projection of 86°11'31"W, 31°31'1"N. The cloud quickly moved northeast from this point, stopped for a few minutes, then moved southwest at a slower pace for the rest of the experiment. The apparent projection from the satellite to the aircraft operating motion is shown in Figure 7. The cloud projection was about 1 degree south and 1 degree west of the release point at R+2 hours 28 minutes.

The early time cloud drift was more northerly than previously observed. This northerly drift in conjunction with an optical tracking error resulted in the apparent cloud drifting outside the range safety firing limits for the beacon and the probe before striations were clearly evident.

The optical tracking system uses two ground sites to follow the cloud, and from these locates the cloud position. During this release, the D3A ground site tracked the neutral cloud, not the striated ion cloud, causing the projection of the ion cloud position to be significantly

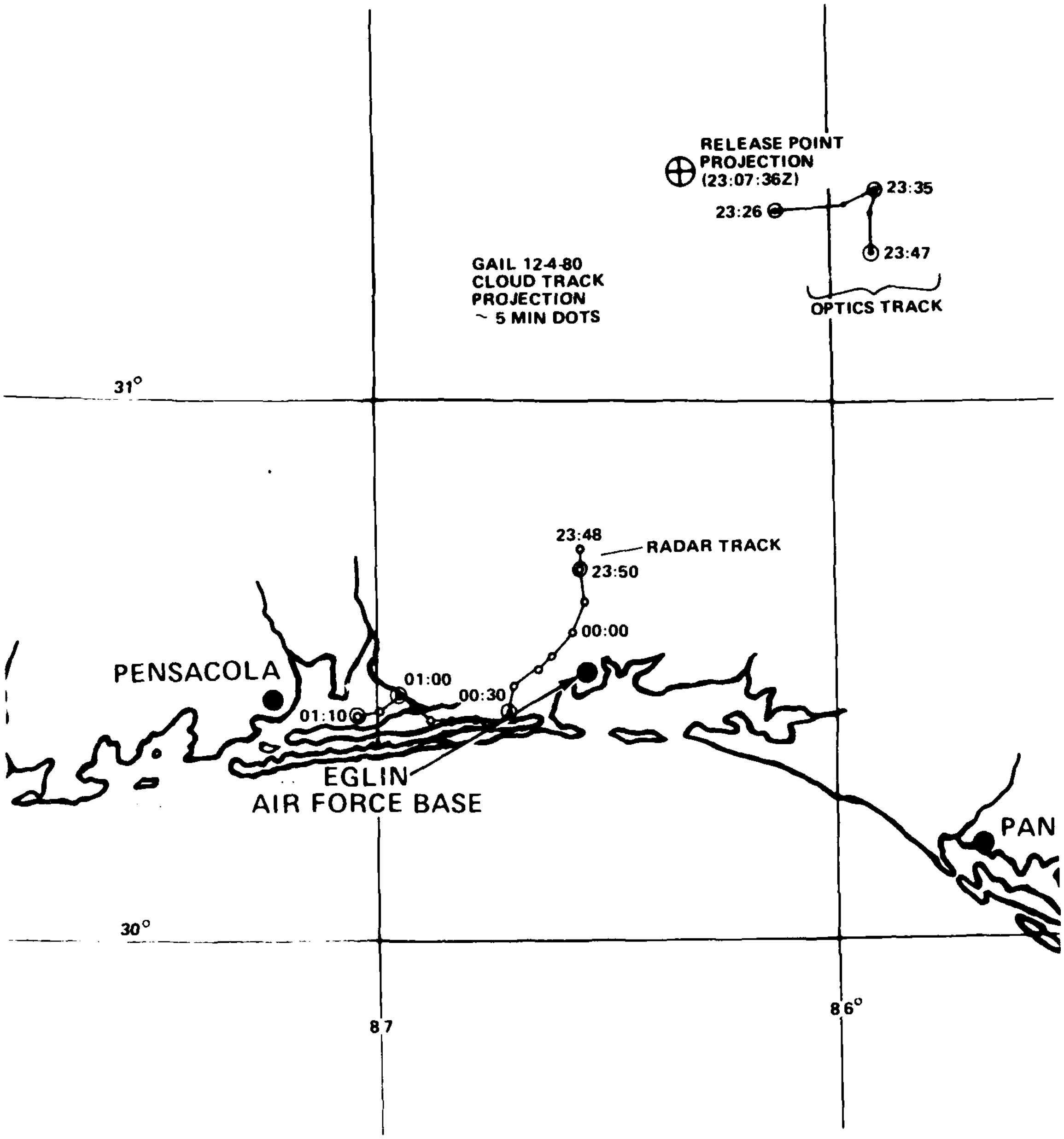

Figure 7. Ion Cloud Track Projection for GAIL

northeast of its actual position. The FPS-85 radar was not working from release (R) to R+20 minutes due to a cable failure. The tracking error is clearly evident in the large jump in the cloud projection point around 2347Z when the track was switched from optics to radar. The aircraft tracking radar was held for missile tracking for the first 21 minutes; thus, the aircraft position during this time must be derived from the less accurate onboard INS data. As a further complication, the radar provided the projection data using the LES-9 satellite ephemeris rather than LES-8. These difficulties resulted in no useful data until approximately 1 hour after release. The aircraft ground track which reflects the difficulty in obtaining good projection data is shown in Figure 8.

The aircraft ground track during each hour and periods of strong (deep) fading are shown in Figures 9, 10 and 11. Since the radar projection was south of the true projection, the first pass of the aircraft through the radar track around 0000Z resulted in no fading and the aircraft was vectored north back toward the last optics track data. It was along this flight path that strong fading was observed (see Figure 10). From that point on the real time aircraft track display and real time fading display were used to position the aircraft.

A total of 32 passes were made with fading seen as late as R+2 hours 45 minutes. A summary of these passes is given in Table 8. Uplink tone data is available when the K-band signal is in phase lock. Moderate to strong fading was seen during 18 of the 19 passes between R+50 minutes and R+1 hour 32 minutes. Weak fading and diffraction ringing were observed between R+1 minute and R+50 minutes. During most of this first 50 minutes, the aircraft was following the incorrect optics track point projection data causing it to traverse the high altitude, low-ion density

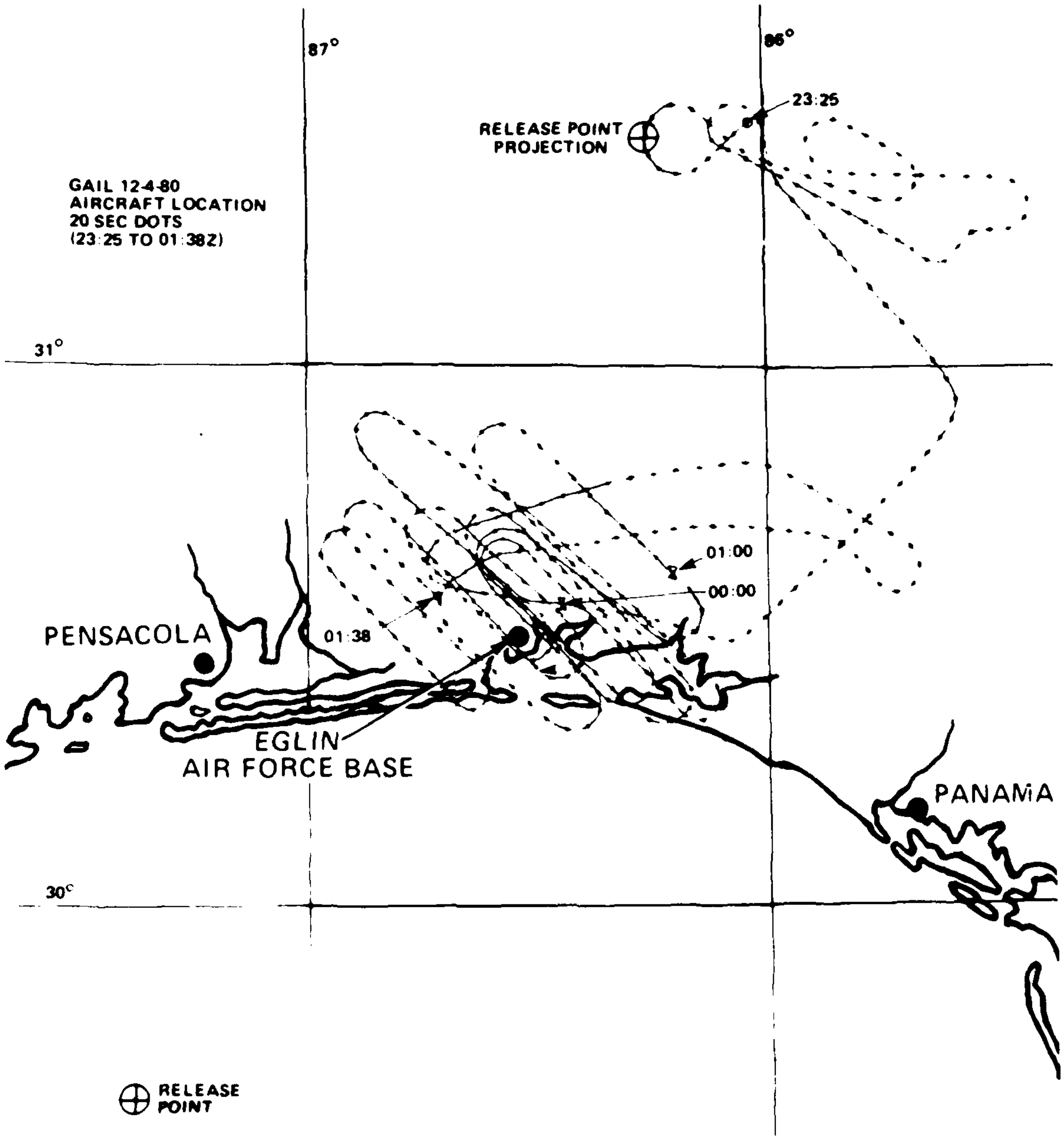

Figure 8. Aircraft Ground Track for GAIL

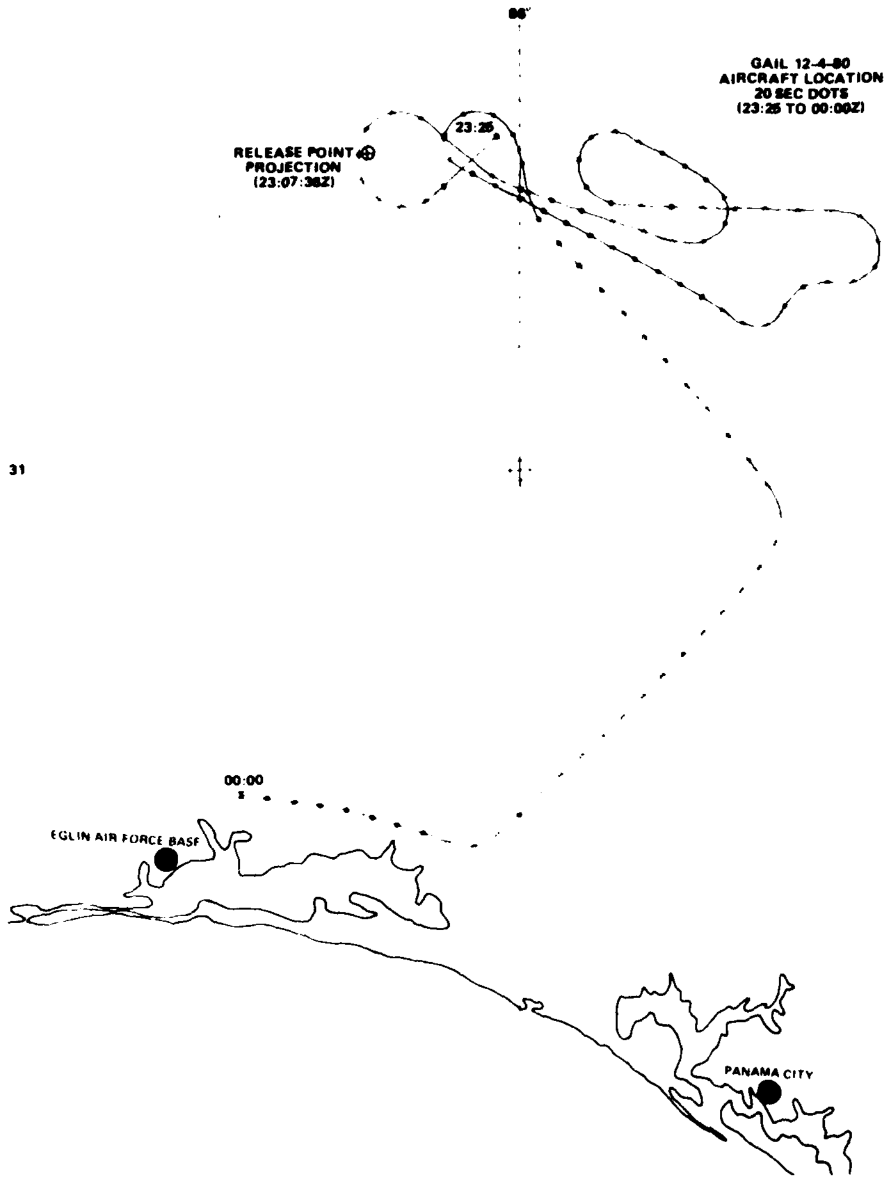

Figure 9. Aircraft Ground Track for GAIL from 23:25 to 00:00Z

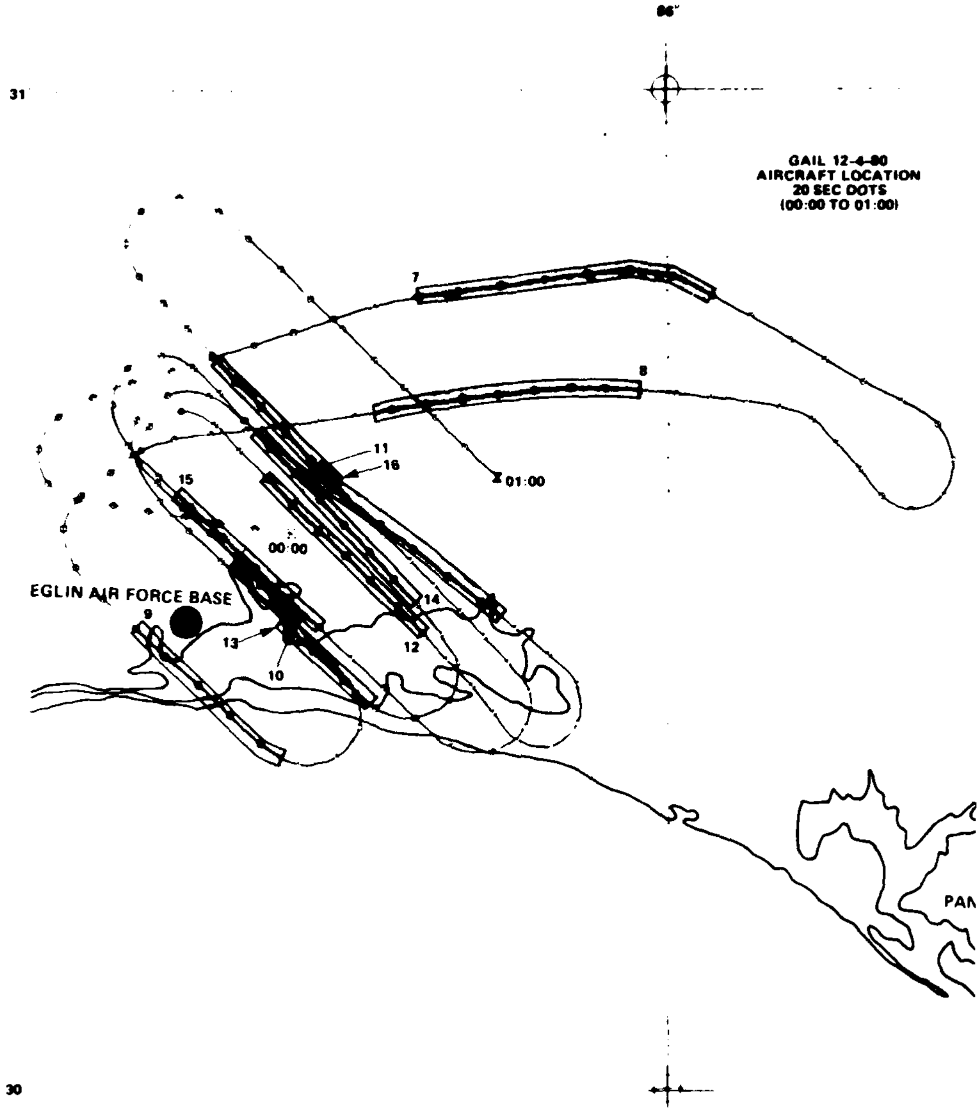

Figure 10. Aircraft Ground Track for GAIL from 00:00 to 01:00Z. Periods of Deep Fading are Shaded

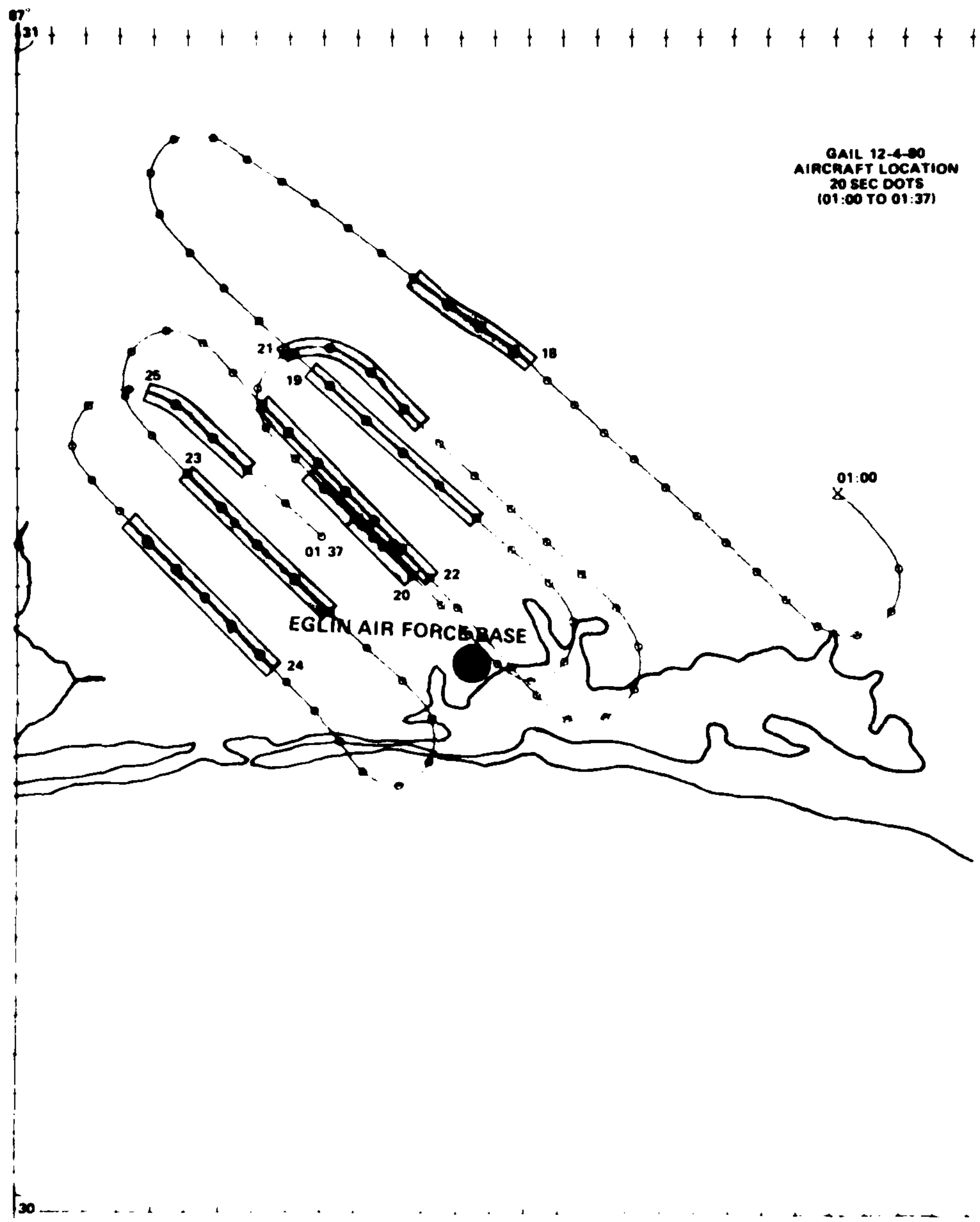

Figure 11. Aircraft Ground Track for GAIL from 01:00 to 01:37Z. Periods of Deep Fading are Shaded

TABLE 8

AIRCRAFT DATA SUMMARY FOR GAIL

Pass No.	Time	K-Lock[1]	Comments
-3	23:07:40-23:09:30	Yes	Diffraction ringing
-2	23:11:50-23:13:30		Diffraction ringing
-1	23:17:40-23:19:30		Weak fading
0	23:24:00-23:26:20		Weak fading
1	23:29:50-23:31:40		Weak fading
2	23:32:40-23:34:20		Weak fading
3	23:35:30-23:37:30	No	Weak fading
4	23:41:40-23:43:20		Weak fading
5	23:48:20-23:50:10		Weak fading
6	23:59:00-00:02:00	No, manual[2] doppler correction	Weak fading
7	00:06:00-00:08:40	No, manual[2] doppler correction	Strong fading
8	00:14:20-00:17:10	Yes	Strong fading
9	00:20:20-00:22:30		Moderate fading
10	00:23:40-00:25:40		Moderate fading
11	00:29:40-00:30:40		Strong fading
12	00:33:00-00:35:50		Strong fading
13	00:37:50-00:39:10		Moderate fading
14	00:41:30-00:44:00	No	Strong fading
15	00:46:30-00:48:30		Strong fading
16	00:49:40-00:55:30		Strong fading, three pieces to cloud
17	00:57:20-01:00:00	No, manual[2] doppler correction	Weak fading
18	01:04:40-01:06:30	No, manual[2] doppler correction	Strong fading

TABLE 8

Concluded

Pass No.	Time	K-Lock[1]	Comments
19	01:10:40-01:12:10	No, manual[2] doppler correction	Strong fading
20	01:14:40-01:16:20	No, manual[2] doppler correction	Strong fading
21	01:17:30-01:18:50	No, manual[2] doppler correction	Strong fading
22	01:23:20-01:25:40	No, manual[2] doppler correction	Strong fading
23	01:27:20-01:29:20	No, manual[2] doppler correction	Strong fading
24	01:32:00-01:34:00	No, manual[2] doppler correction	Strong fading
25	01:35:20-01:36:40	No, manual[2] doppler correction	Strong fading, short interval
26	01:39:30-01:42:00	No, manual[2] doppler correction	No fading
27	01:42:00-01:46:00	No, manual[2] doppler correction	No fading/possibly weak fading
28	01:48:00-01:52:00	No, manual[2] doppler correction	No fading/possibly weak fading

[1]Loss of k-lock implies loss of uplink tone data.

[2]Manual doppler correction on downlink tone.

part of the cloud, northeast of the cloud center. Only weak fading was seen during the last two passes. Uplink data is available for 12 of the 32 passes while downlink data is available for all 32 passes.

The data received from each of these releases shows the expected progression of effects from diffraction ringing, large defocusing from the background ion cloud, large defocus with superimposed fading from developing striations, and eventually random fading at late times. Representative data are described below.

Two examples of early time passes are given in Figures 12 and 13, taken from the real time strip charts onboard the aircraft. These passes show early time diffraction or multipath ringing characterized by oscillating amplitude fluctuations. This diffraction ringing was noted almost immediately following each release. This can be contrasted to the strong deep fading seen in Figure 14 for Pass 11 which shows what is termed strong fading characteristic of well developed striations. The last strong fading of the night for GAIL is shown in Figure 15. It is interesting to note the coarseness or slower fading that results at late time.

TEST RESULTS FOR HOPE

The second barium release call HOPE occurred on 6 December 1980, at 23:07:37.4. It was released at an altitude of 179.4 kilometers at an approximate latitude and longitude of 29.25°N and 87.0°W. This release point was about 5 minutes southwest of the planned release point. This cloud appears to have moved north-northeast for a few minutes, stopped, then moved south-southwest at a moderate velocity for the rest of the night. The cloud projection was located about 2 degrees south and 1.5

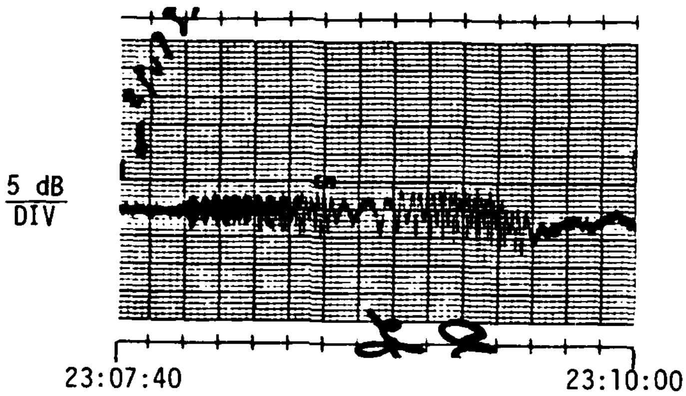

Figure 12. Downlink Fading on GAIL Pass 3, R+1 Minute

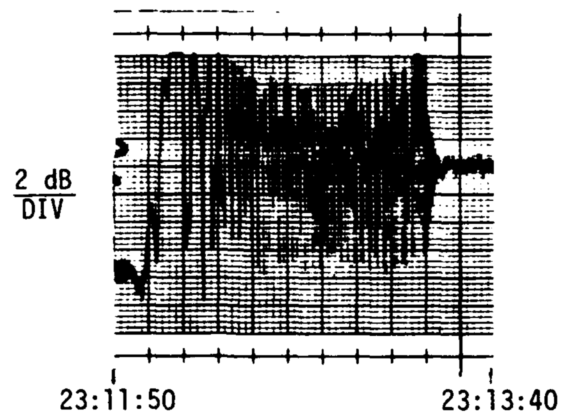

Figure 13. Downlink Fading on GAIL Pass 2, R+5 Minutes

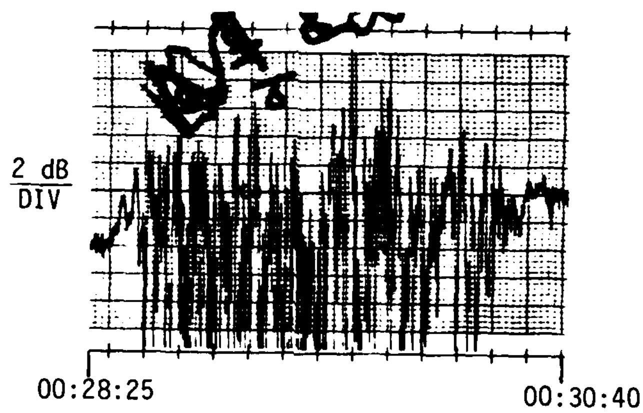

Figure 14. Downlink Fading on GAIL Pass 11, R+1^{h}25^m

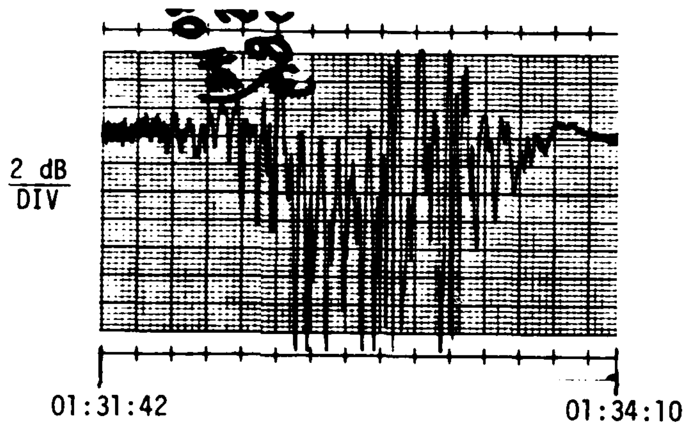

Figure 15. Downlink Fading on GAIL Pass 24, R+2^{h}25^m

degrees west of release at R+2 hours 38 minutes. A plot of the available cloud projection data is shown on Figure 16. The aircraft ground track is shown on Figure 17.

Optical track data was used until about R+55 minutes with radar track data being used for the remainder of the experiment. The optics track located the cloud somewhat north of the radar track. The radar tracks appear to have been more consistent with the observed fading. As shown on Figure 17 the aircraft was vectored nearly 0.5 degree south of the optics track ground around 0000Z. The aircraft ground tracks for each hour period are shown in Figures 18, 19 and 20. The intervals of strong fading are indicated by the shading.

The ion cloud from HOPE drifted more northerly than during GAIL and again resulted in an inability to launch a beacon or a probe rocket.

A total of 33 passes were made during this release with 14 showing moderate to strong fading. A summary of all of the passes is given in Table 9. The last pass ended at R+2 hours 57 minutes while the last pass with moderate fading observed ended at R+2 hours 22 minutes. The first 11 passes, which were between release and R+55 minutes, showed strong fading in only two passes and diffraction ringing in one. These passes were made while the aircraft followed the optics cloud track. The time between R+55 minutes and R+1 hour 3 minutes was spent catching up with the cloud which was south of the aircraft. Twelve of the next 15 passes showed moderate to strong fading yielding the total of 14 good passes. Pass 26 is interesting because it shows only one deep fade that may be due to a single object. The last seven passes showed weak fading or no fading.

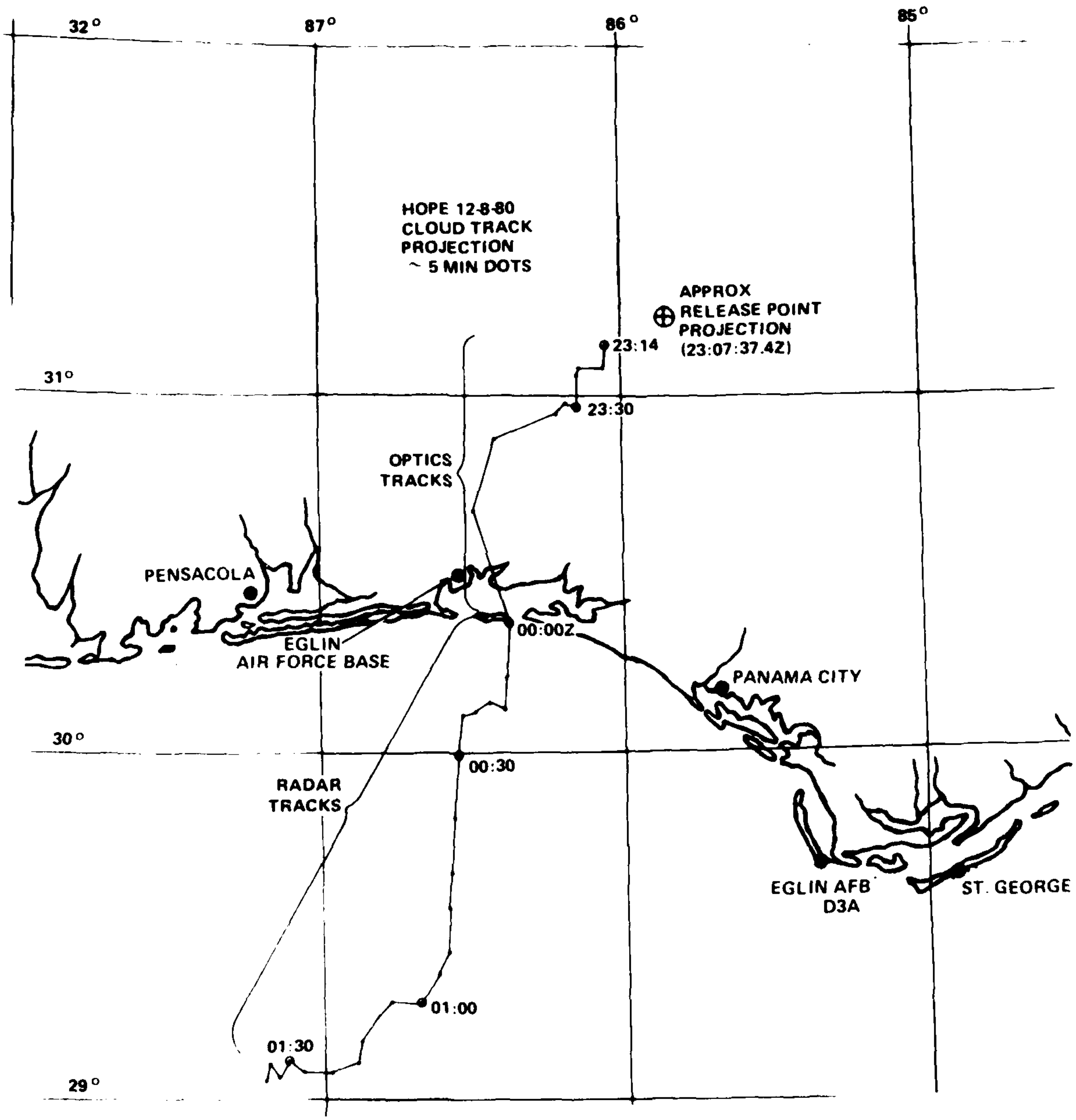

Figure 16. Ion Cloud Track Projection for HOPE

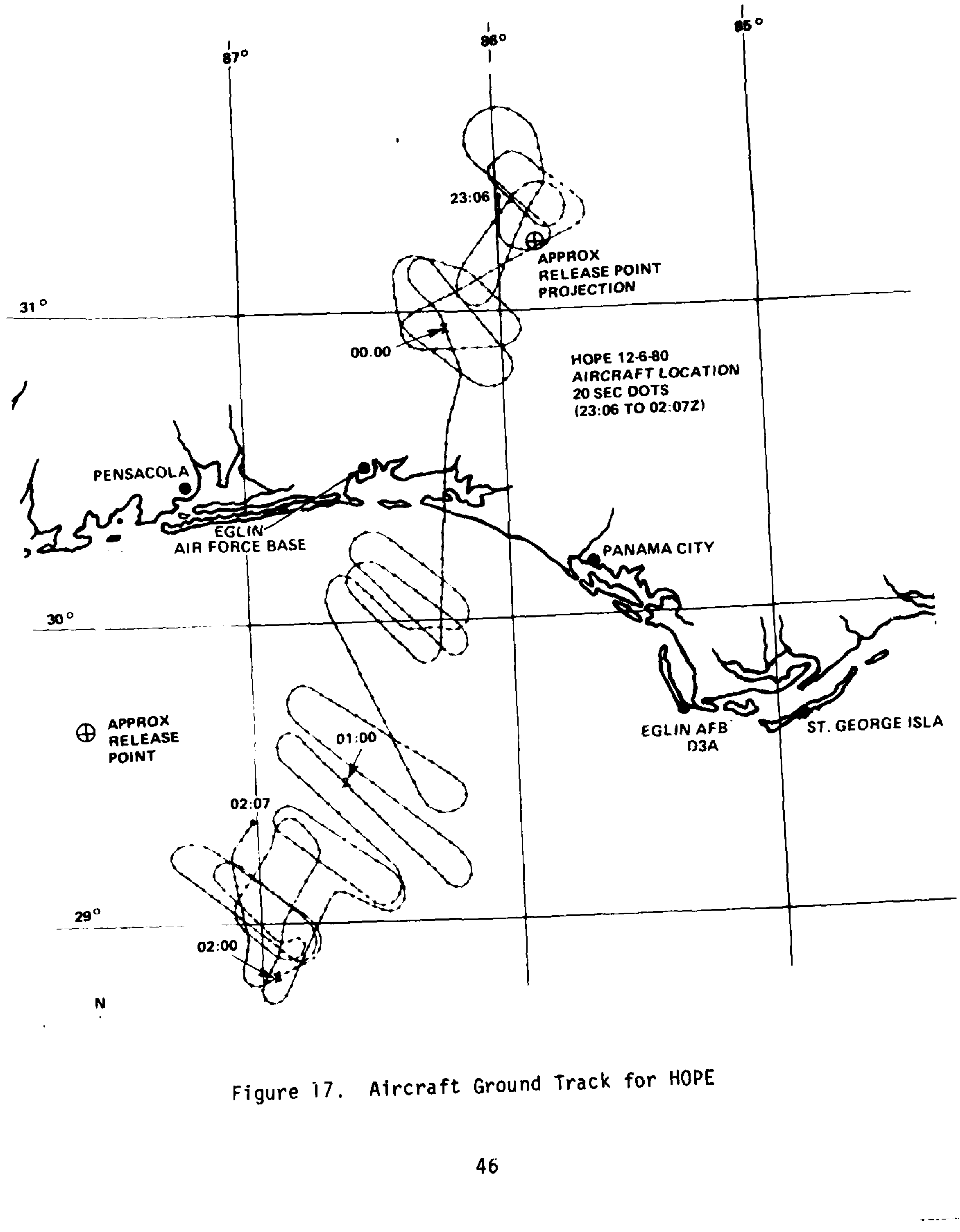

Figure 17. Aircraft Ground Track for HOPE

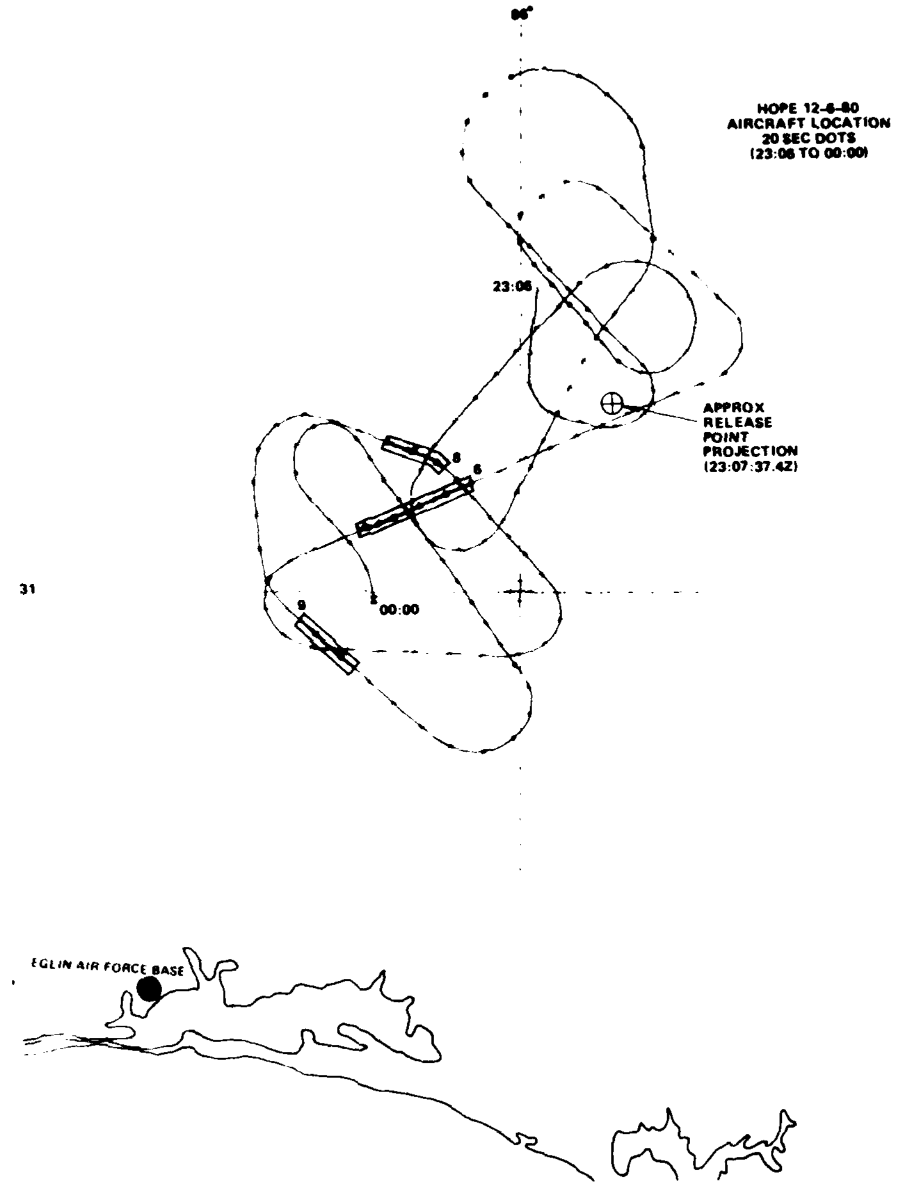

Figure 18. Aircraft Ground Track for HOPE from 23:06 to 00:00Z. Periods of Deep Fading are Shaded

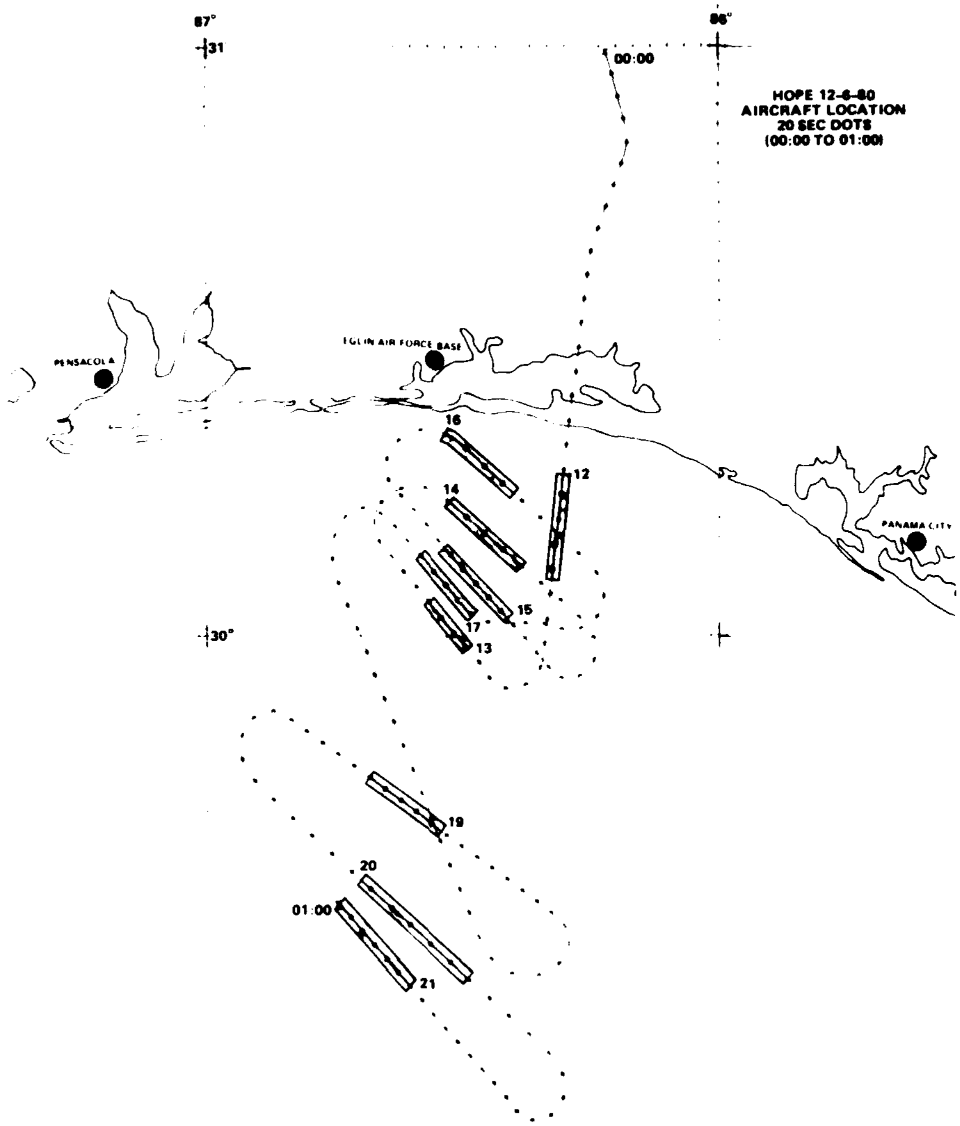

Figure 19. Aircraft Ground Track for HOPE for 00:00 to 01:00. Periods of Deep Fading are Shaded

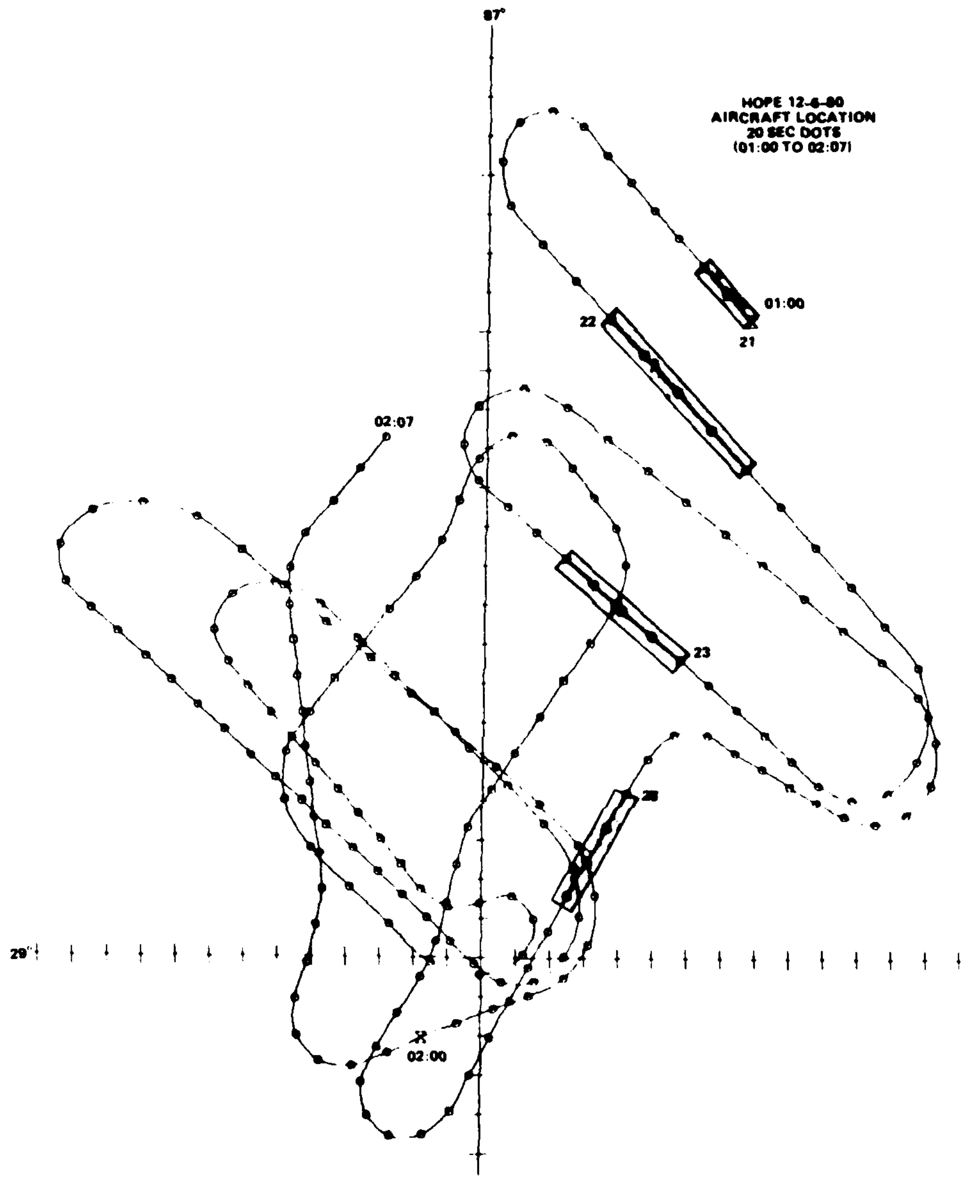

Figure 20. Aircraft Ground Track for HOPE from 01:00 to 02:07. Periods of Deep Fading are Shaded

TABLE 9

AIRCRAFT DATA SUMMARY FOR HOPE

Pass No.	Time	K-Lock	Comments
1	23:07:30-23:11:40	No	Diffraction ringing, large defocus of ~15 dB
2	23:17:40-23:20:00	Yes	No fading
3	23:22:00-23:24:00		Weak diffraction ringing
4	23:27:30-23:29:10		Very little fading
5	23:30:50-23:32:20		Very little fading
6	23:36:20-23:38:40	?, uplink OK	Strong fading, large defocus of ~15 dB
7	23:40:30-23:42:00	Yes	Little fading
8	23:45:00-23:47:00		Strong fading, partially in turn
9	23:49:50-23:51:30		Moderate fading
10	23:54:00-23:57:00		No fading
11	00:00:00-00:01:00		No fading
12	00:05:40-00:07:50		Moderate diffraction ringing
13	00:10:00-00:12:00		No fading
14	00:14:00-00:16:20		Strong fading
15	00:18:20-00:21:40		Strong fading
16	00:23:30-00:15:00		Strong fading
17	00:29:00-00:31:20		Strong fading
18	00:36:30-00:38:00		Little fading
19	00:42:30-00:45:20		Strong fading
20	00:50:00-00:52:10		Strong fading first minute
21	00:56:00-01:02:00		Strong fading in 00:59:20 to 01:01:20
22	01:04:30-01:06:20		Strong fading
23	01:10:50-01:12:40		Moderate fading
24	01:15:30-01:17:00	?, uplink OK	Moderate fading
25	01:21:00-01:23:20	Yes	Weak fading
26	01:28:20-01:29:30		One deep fade

TABLE 9

CONCLUDED

Pass No.	Time	K-Lock	Comments
27	01:34:00-01:36:00	Yes	Weak fading
28	01:36:00-01:37:00		Weak fading
29	01:39:20-01:41:10		Weak fading
30	01:44:00-01:45:00		No fading
31	01:49:00-01:53:00		No fading
32	01:53:00-01:55:00		No fading
33	02:02:00-02:04:00		Weak fading

Uplink data is available for 32 of the 33 passes and downlink data is available for all 33 passes. K-band lock was lost during part of one pass making the uplink data questionable during that pass. Occasionally, as noted, a loss of lock indication was obtained, but, the uplink data appeared unperturbed.

A few samples of the data from HOPE are given in Figures 21 through 25. These data have been preliminary computer processed for this quick-look report. Additional processing is planned. Pass 1 shown in Figure 21 shows an unusually large defocus of nearly -20 dB with some diffraction ringing at the edges. The depth and duration of this defocus, lasting approximately 75 seconds is remarkable. Defocusing of this magnitude was not observed during the prior STRESS experiment and is believed to be due in part to the alignment of the propagation path and the ion cloud drift (stretching) direction. If the initial stretching direction was approximately along 40 degrees azimuth and since the azimuth to the satellite at early times was approximately 210 degrees, then the ray path would make an angle of about 10 degrees with the stretching direction of the cloud.

A plot of azimuth angle and elevation variation from the 662 aircraft to the LES-8 satellite for all four PLACES releases is given in Figure 26. By far the largest component of the change with time is due to the satellite motion. The azimuth and elevation both increase by approximately 18 degrees over a typical 3 hour period. The azimuth angle typically started near 207 degrees at 2300Z and ended near 227 degrees at 0200Z. Likewise, the elevation angle started near 34 degrees at 2300Z and ended near 51 degrees at 0200Z. Generally, it was desired to have an elevation angle in excess of 30 degrees throughout the test.

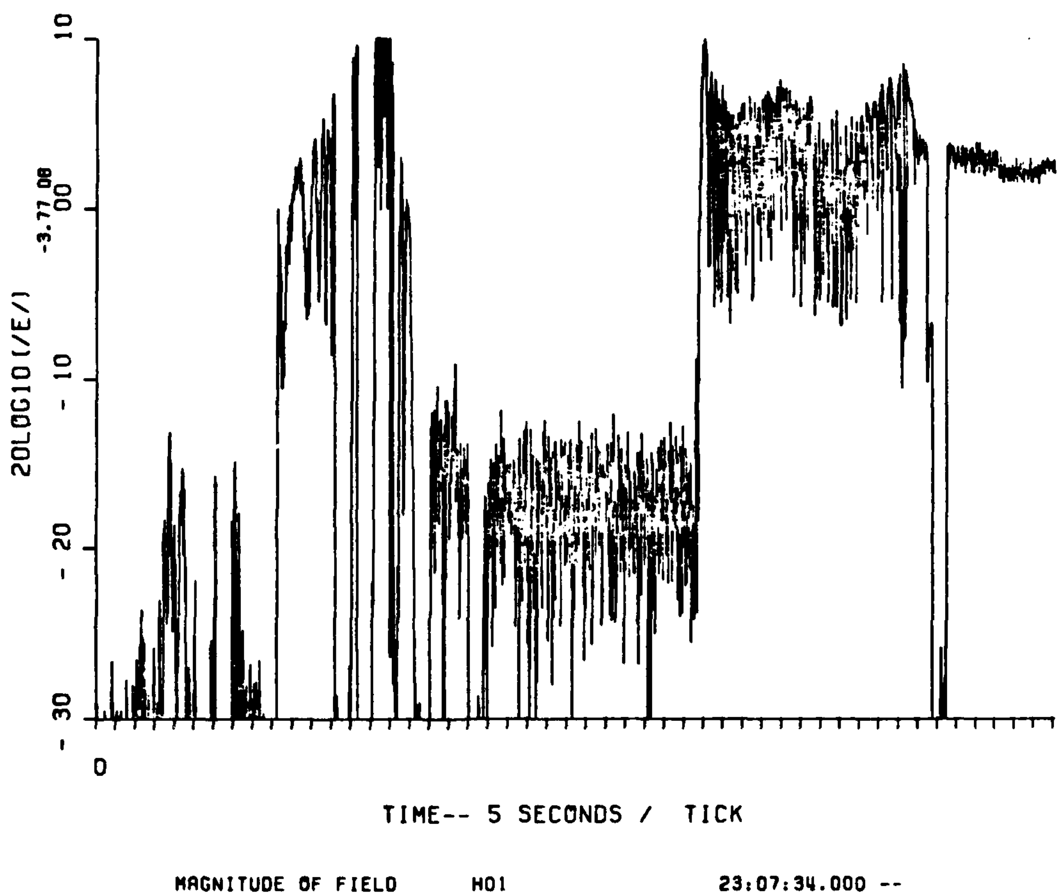

Figure 21. Downlink Fading on HOPE Pass 1, R+1 Minute

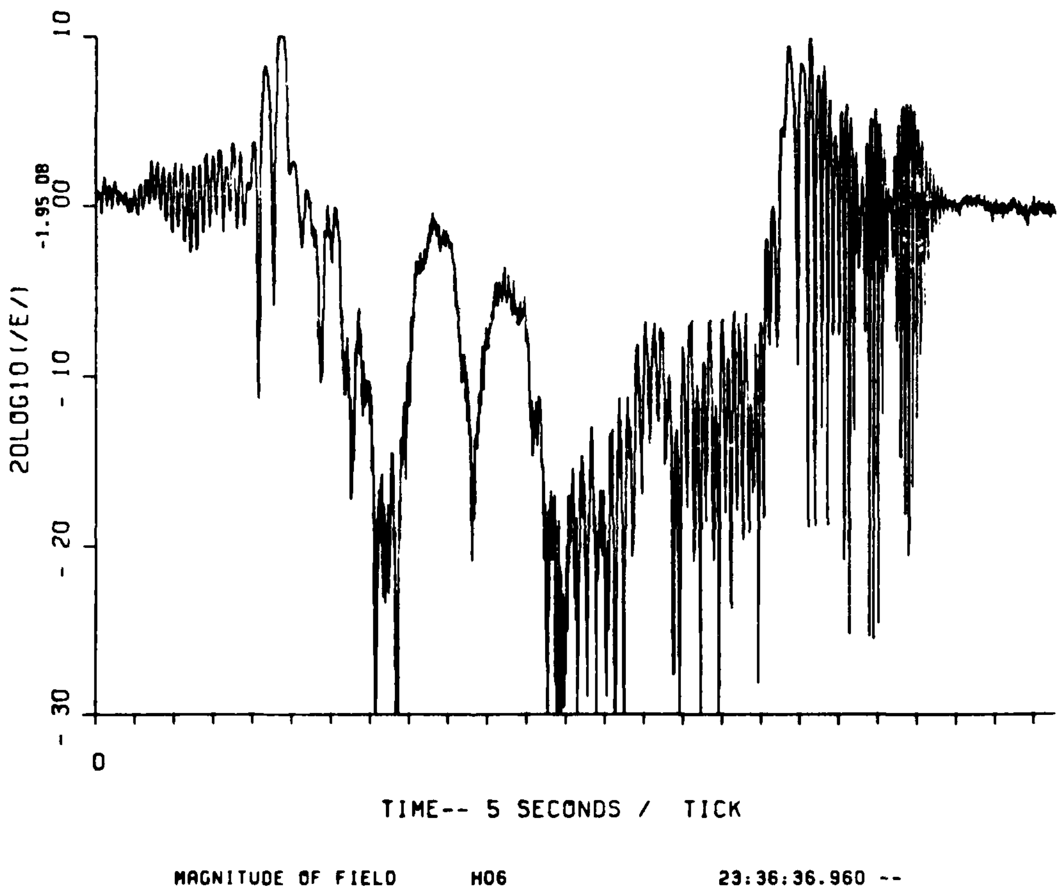

Figure 22. Downlink Fading on HOPE Pass 6, R+30 Minutes

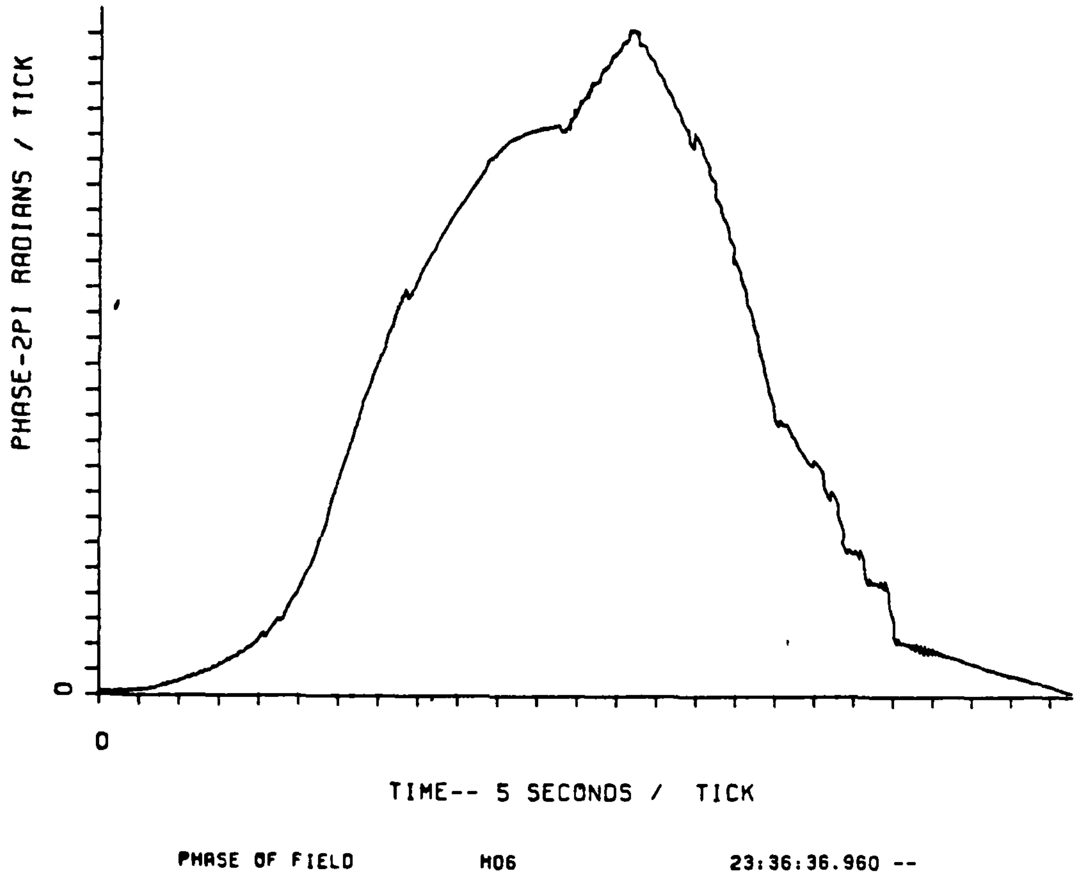

Figure 23. Downlink Phase Effects on HOPE Pass 6, R+30 Minutes

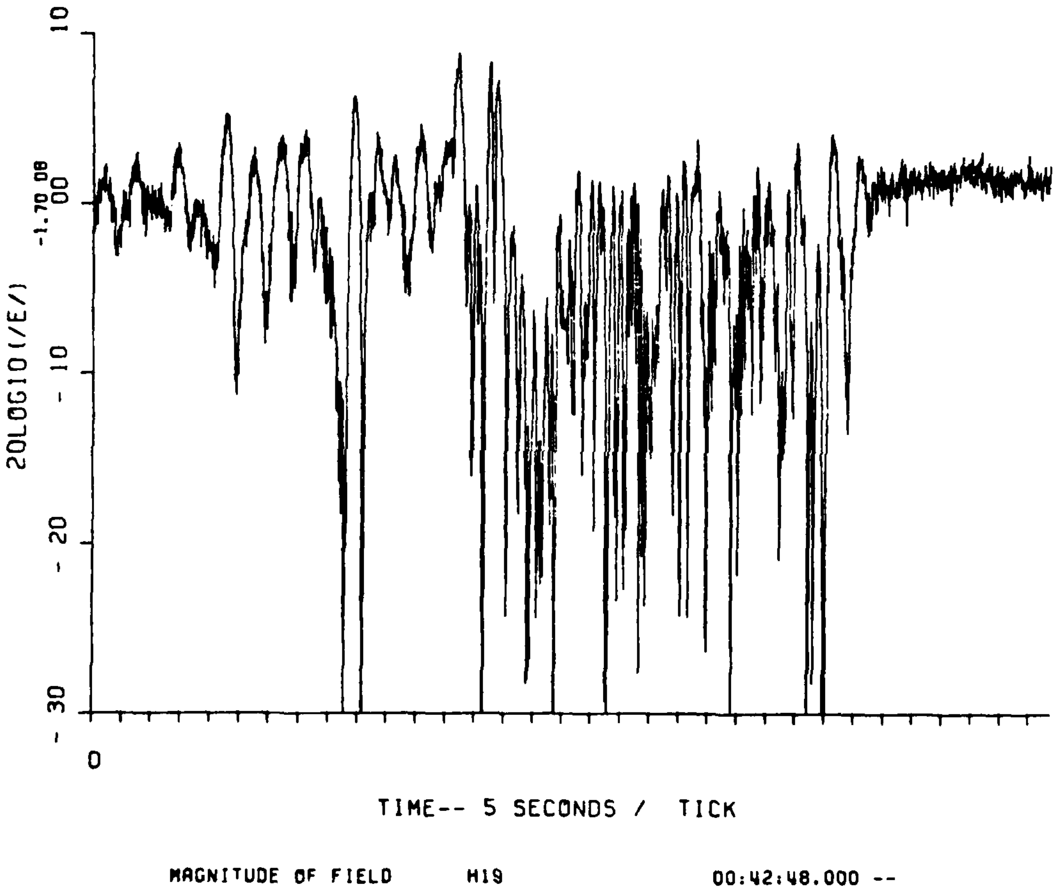

Figure 24. Downlink Fading on HOPE Pass 19, R+1^{h}37^{m}.

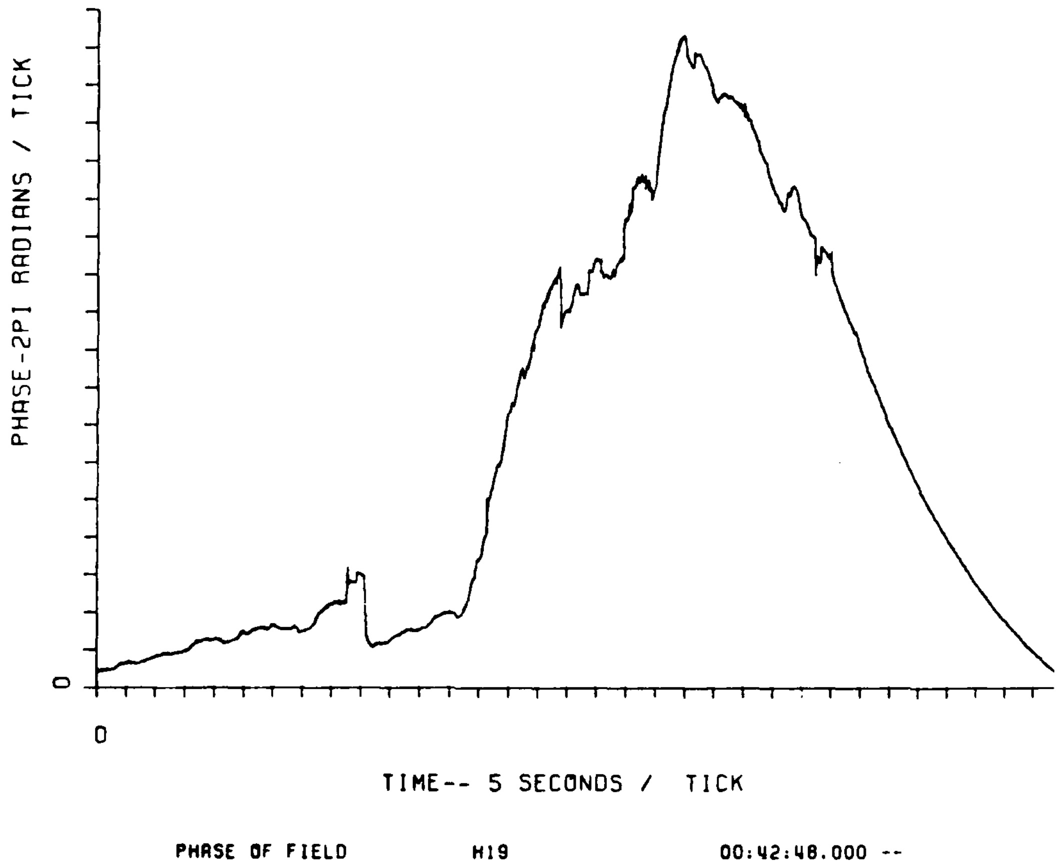

Figure 25. Downlink Phase Effects on HOPE Pass 19, R+1^{h}37^m

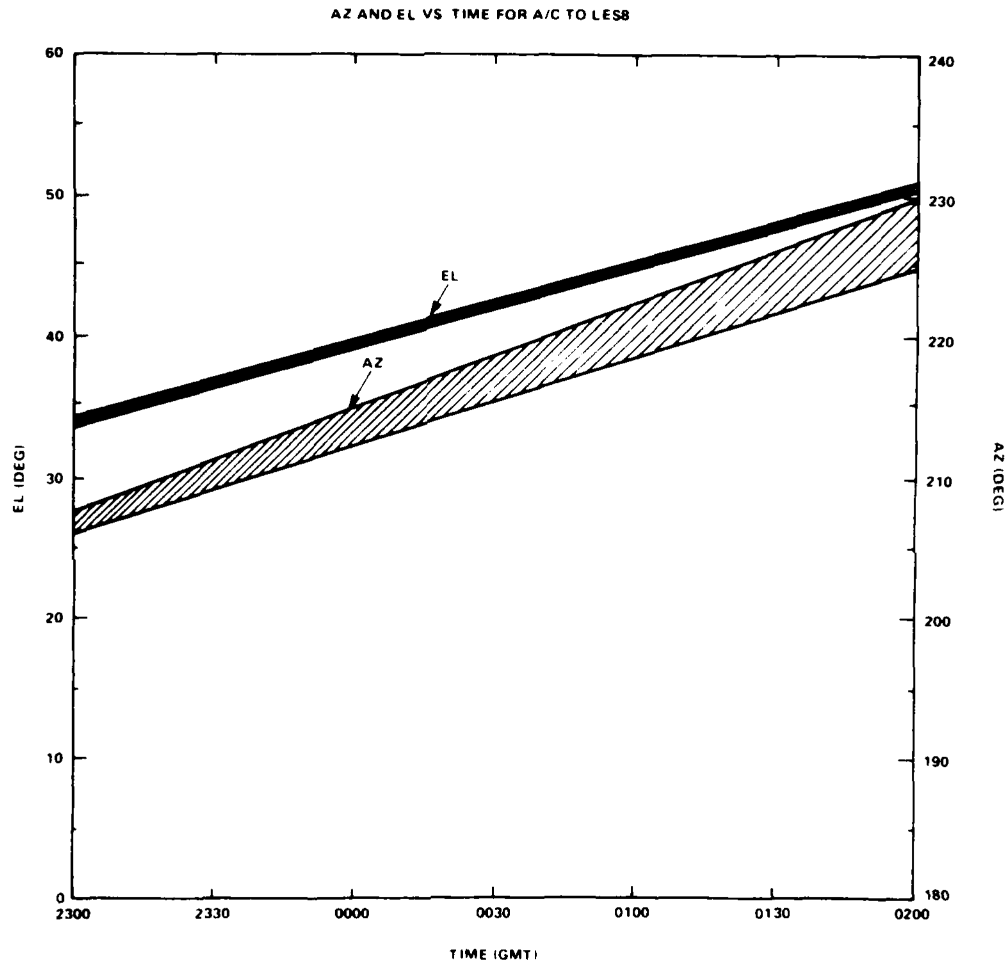

Figure 36. Azimuth and Elevation Angle to LES-8 Versus Time During PLACES

As time progresses, Pass 6 at R+30 minutes (Figures 22 and 23) shows the development of some structuring superimposed on this still large defocus. This structuring is evident in the amplitude and phase characteristics in the latter half of the pass (cloud). Data for Pass 19 at 1 hour and 37 minutes is shown in Figures 24 and 25. Again, the slower fading amplitude characteristics and smaller integrated electron content (less phase windup) of the background ion cloud are evident. These figures are indicative of the processed data quality available. The processing bandwidth can be reduced to improve signal quality still further in subsequent planned processing.

TEST RESULTS FOR IRIS

The third barium release, IRIS, was on 8 December 1980 and occurred at 23:13:06.7. It was released at an altitude of 179.6 kilometers and a latitude and longitude of 28.799°N and 87.166°W. The projection of this release point is 30°40'11"N. and 85°51'24"W. The cloud projection moved in a south-southeast direction during the entire experiment and was last seen about 3 degrees south and 0.75 degrees east of the release point projection at R+2 hours 30 minutes. Plots of the cloud track projection and aircraft ground track are in Figures 27 and 28 The aircraft ground tracks for each hour are shown in Figures 29, 30 and 31 with intervals of strong fading indicated.

No cloud tracking data was available between release and R+12 minutes. Optics track data was used from R+12 minutes and R+15 minutes and radar track data was used thereafter. The release being low and west of the planned release point resulted in the radar not acquiring the release as planned. The radar track provided a consistent indication of the striation location throughout the night.

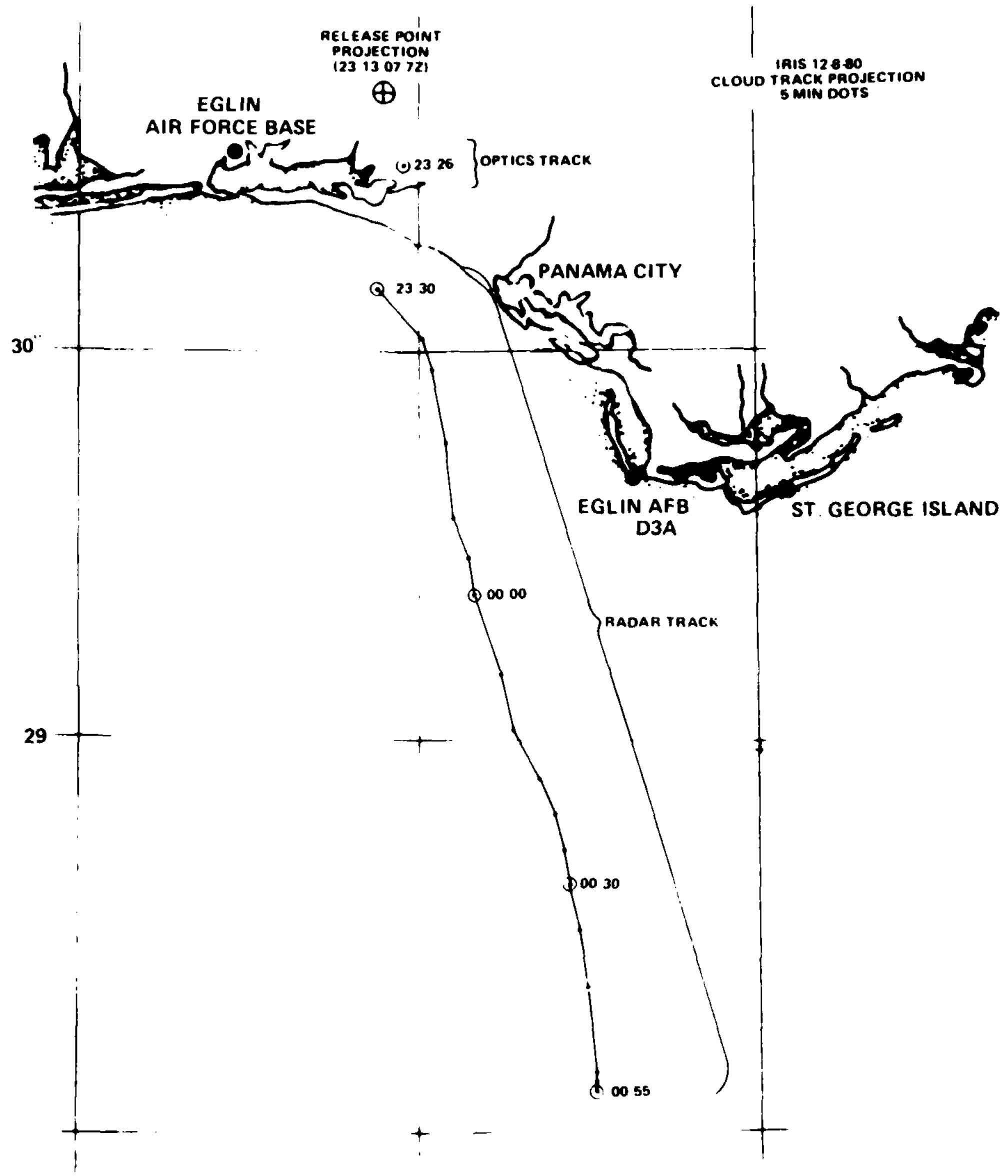

Figure 27. Ion Cloud Track Projection for IRIS

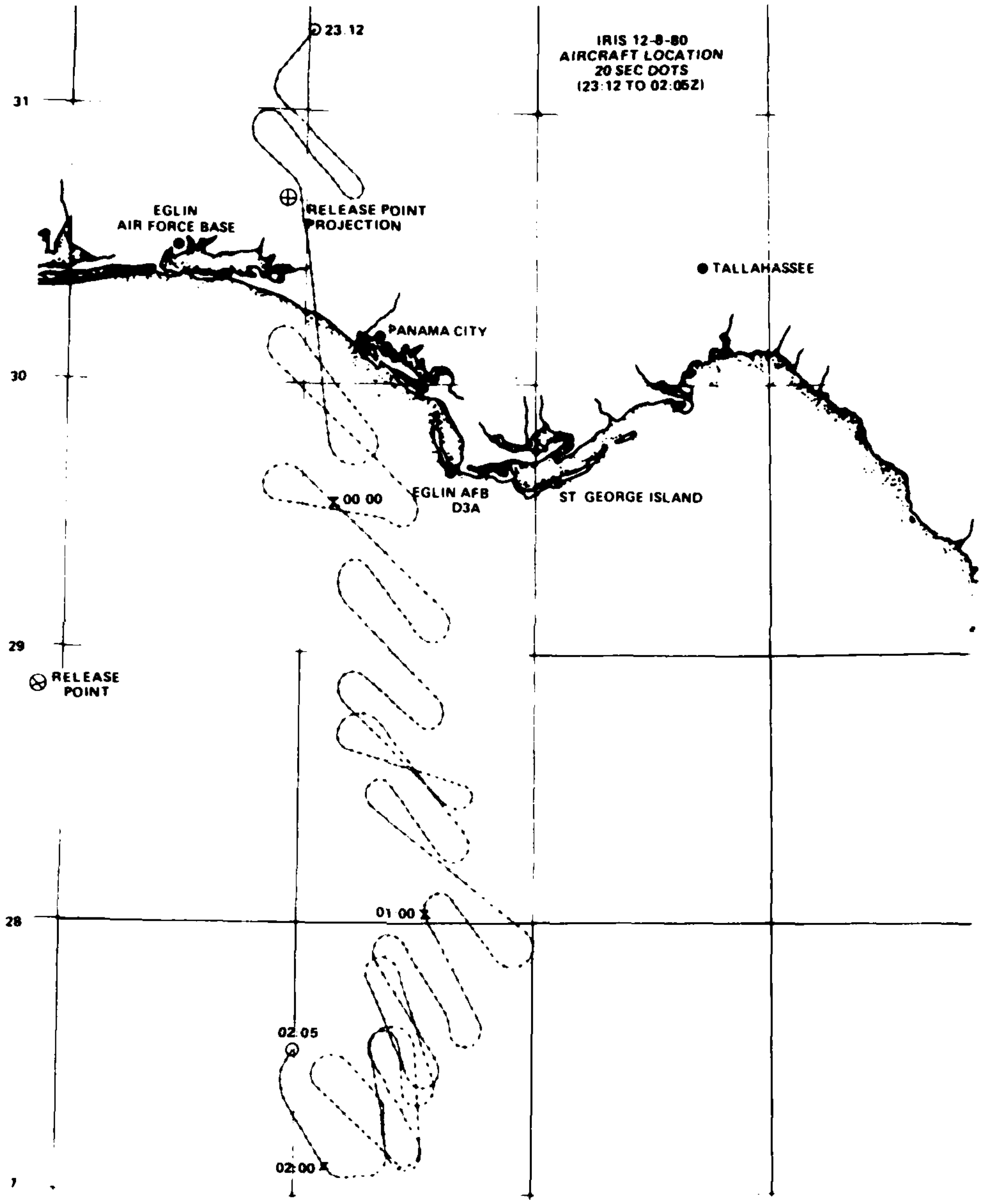

Figure 28. Aircraft Ground Track for IRIS

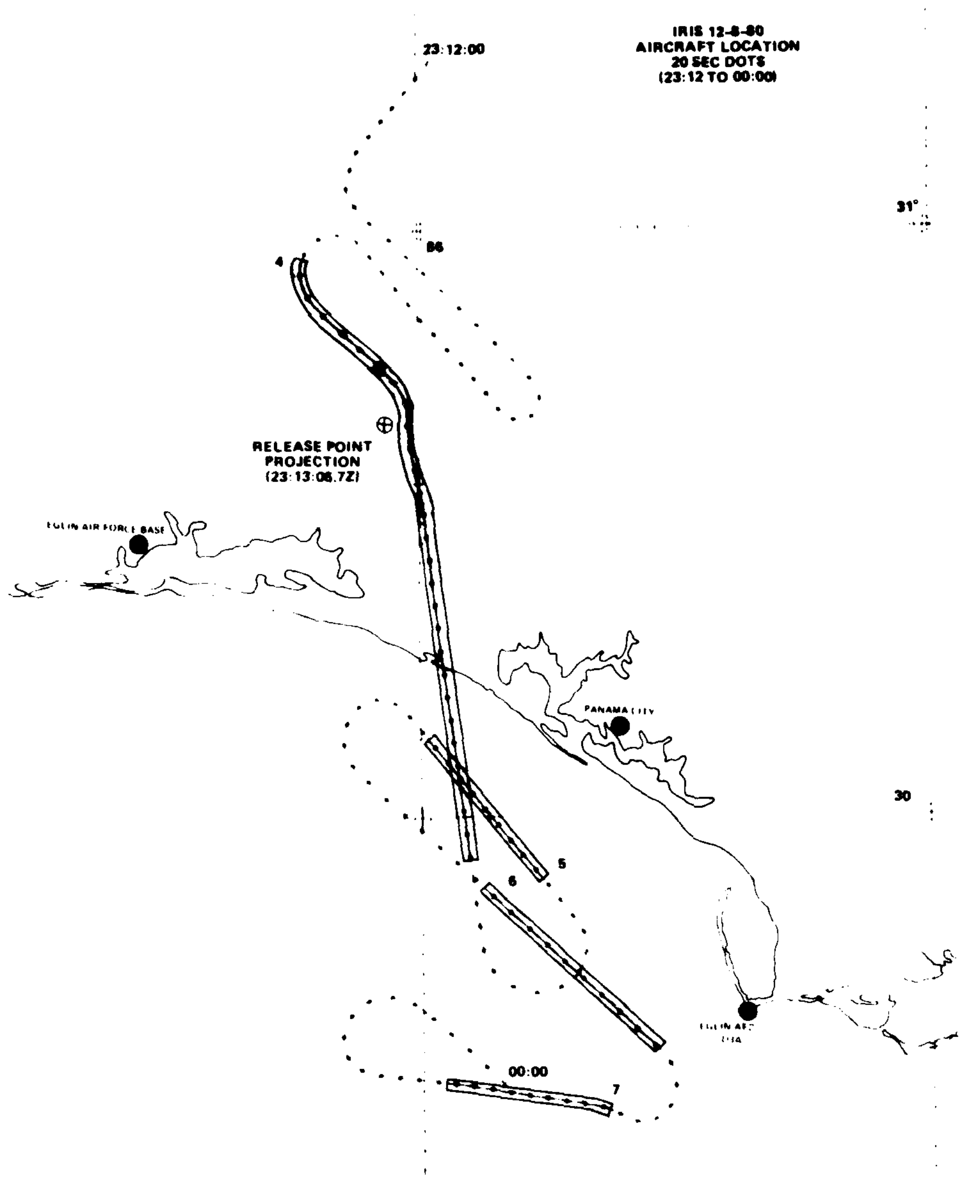

Figure 29. Aircraft Ground Track for IRIS from 23:12 to 00:00Z. Periods of Deep Fading are Shaded

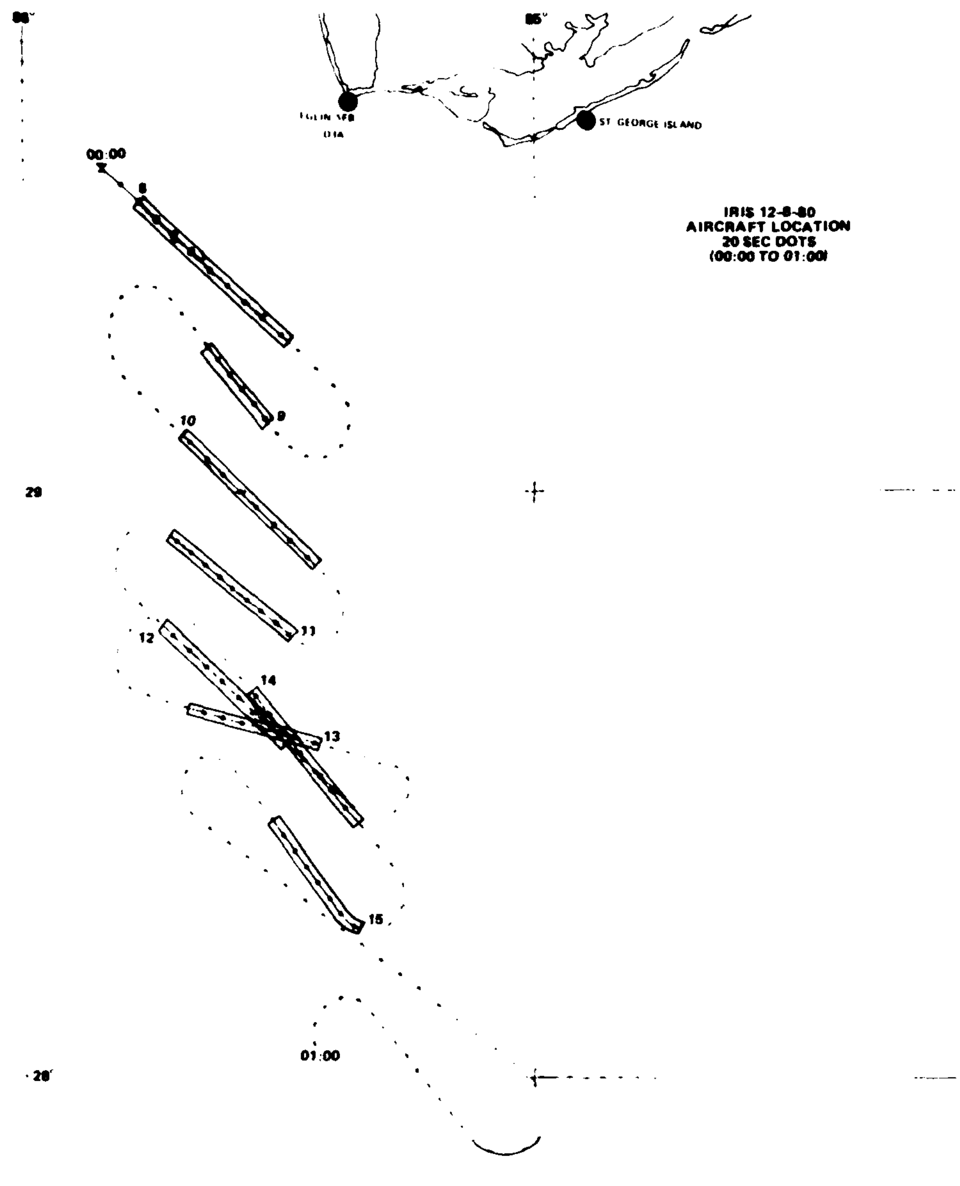

Figure 30. Aircraft Ground Track for IRIS from 00:00 to 01:00Z. Periods of Deep Fading are Shaded

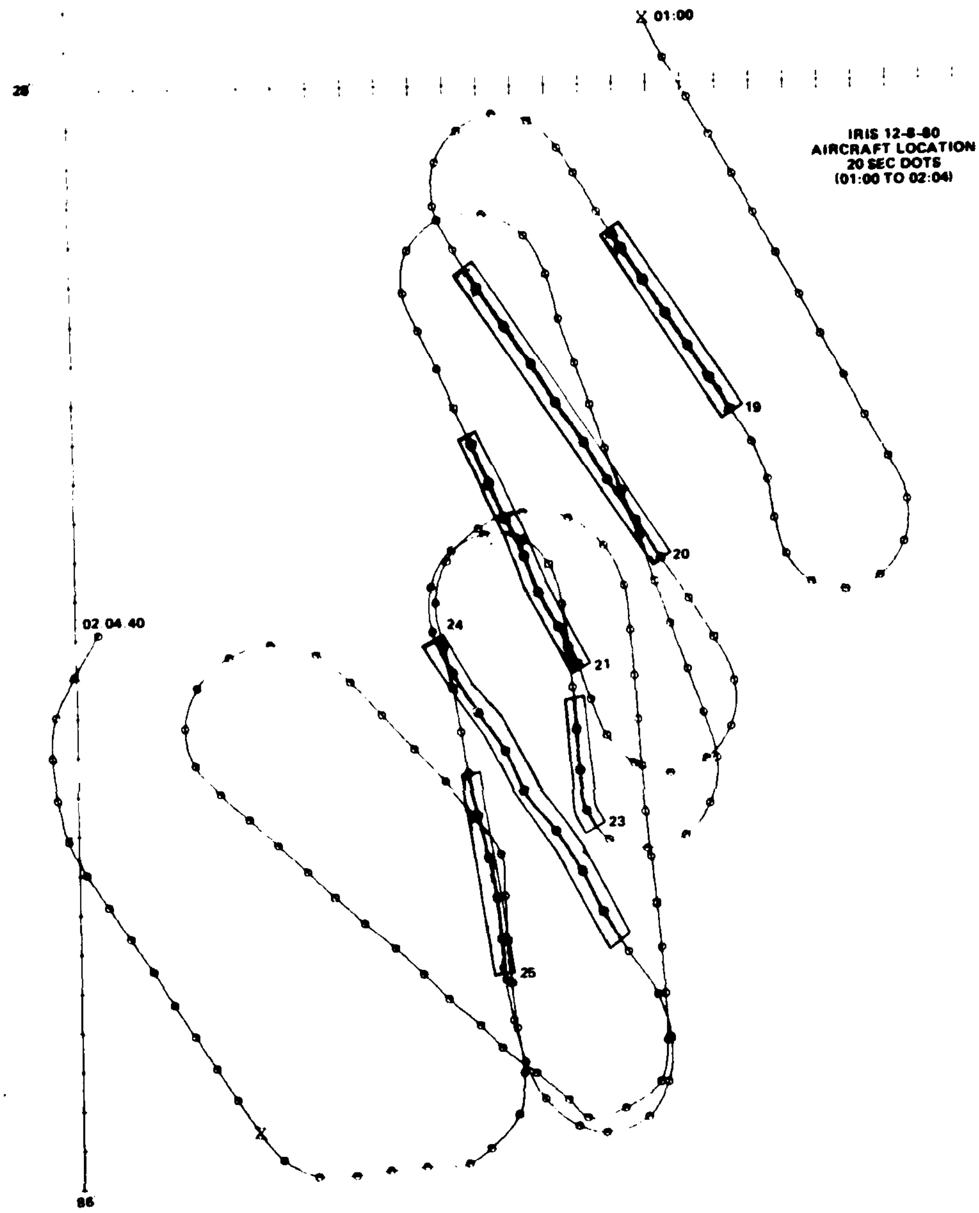

Figure 31. Aircraft Ground Track for IRIS from 01:00 to 02:04Z. Periods of Deep Fading are Shaded

A total of 31 passes were made ending at R+2 hours 48 minutes. A summary of these passes is given in Table 10. The first strong fading was seen at R+16 minutes, the fourth pass. Moderate to strong fading ending at R+2 hours 26 minutes. The last fading seen ended at R+2 hours 44 minutes during Pass 29.

Downlink data is available for all 31 passes. K-band lock was never achieved during this experiment due to an oscillator failure, consequently no usable uplink data was recorded. Manual doppler correction was used throughout the night. Prior analyses (Prettie, 1979) have shown that the uncompensated doppler will not corrupt the phase power spectal density data, but will make processing somewhat more difficult.

Two beacon rockets were fired during this release, both resulting in good data. Because of the extreme southern drift of the cloud, a 40 kilometer occultation distance had to be used to stay within the range safety limits. The data received from both beacon rockets matches very closely with predicted data in the pre-experiment test plan.

Sample plots of the downlink amplitude fading for IRIS are given in Figures 32 through 41. Passes 4 and 5 (R+18 minutes and R+26 minutes) shown in Figures 32 and 33 show a large -15 dB defocus with rapid deep fading indicative of structure formation. As the ion cloud was stretched southeast more perpendicular to the propagation path, this defocus is believed to be indicative of a high ion cloud density and not a geometric artifact. While not shown here, a quick look at the phase power spectral density obtained near the first beacon occultation (Pass 5) also indicates a very strongly structured cloud. The phase PSD height at 1 Hz is approximately 5 dB higher than that obtained during Pass 10 of the STRESS event

TABLE 10

AIRCRAFT DATA SUMMARY FOR IRIS

Pass No.	Time	K-Lock	Comments
1	23:15:30-23:18:10	No, manual doppler correction	No fading
2	23:19:40-23:23:10	No, manual doppler correction	Weak diffraction ringing
3	23:25:10-23:28:20	No, manual doppler correction	No fading
4	23:29:20-23:34:20	No, manual doppler correction	Strong fading, large defocus
5	23:38:30-23:41:30	No, manual doppler correction	Strong fading, large defocus, second fading object
6	23:46:30-23:49:40	No, manual doppler correction	Strong fading
7	23:51:50-23:54:50	No, manual doppler correction	Strong fading
8	00:00:40-00:03:30	No, manual doppler correction	Strong fading
9	00:06:50-00:08:30	No, manual doppler correction	Strong fading
10	00:13:20-00:15:50	No, manual doppler correction	Strong fading
11	00:18:10-00:20:40	No, manual doppler correction	Strong fading

TABLE 10

Continued

Pass No.	Time	K-Lock	Comments
12	00:23:20-00:26:00	No, manual doppler correction	Strong fading
13	00:30:30-00:32:50	No, manual doppler correction	Strong fading
14	00:37:00-00:39:40	Yes, no uplink tone	Weak fading
15	00:41:50-00:44:20	Yes, no uplink tone	Strong fading
16	00:48:00-00:52:00	Yes	No fading
17	00:56:00-00:58:00	Yes	No fading
18	01:00:40-01:03:40	No, manual doppler correction	No fading
19	01:07:00-01:08:50	No, manual doppler correction	Moderate fading
20	01:11:50-01:14:20	No, manual doppler correction	Strong fading
21	01:17:50-01:20:00	No, manual doppler correction	Strong fading
22	01:23:30-01:26:00	No, manual doppler correction	No fading
23	01:27:50-01:29:20	No, manual doppler correction	Moderate fading
24	01:31:30-01:34:10	No, manual doppler correction	Moderate fading
25	01:38:00-01:39:40	No, manual doppler correction	Moderate fading

TABLE 10

CONCLUDED

Pass No.	Time	K-Lock	Comments
26	01:44:00-01:46:00	No, manual doppler correction	No fading
27	01:47:30-01:49:40	No, manual doppler correction	Weak fading
28	01:54:00-01:55:00	No, manual doppler correction	No fading
29	01:56:00-01:57-00	No, manual doppler correction	Weak fading
30	01:58:00-01:59:00	No, manual doppler correction	No fading
31	02:00:00-02:01:30	No, manual doppler correction	No fading

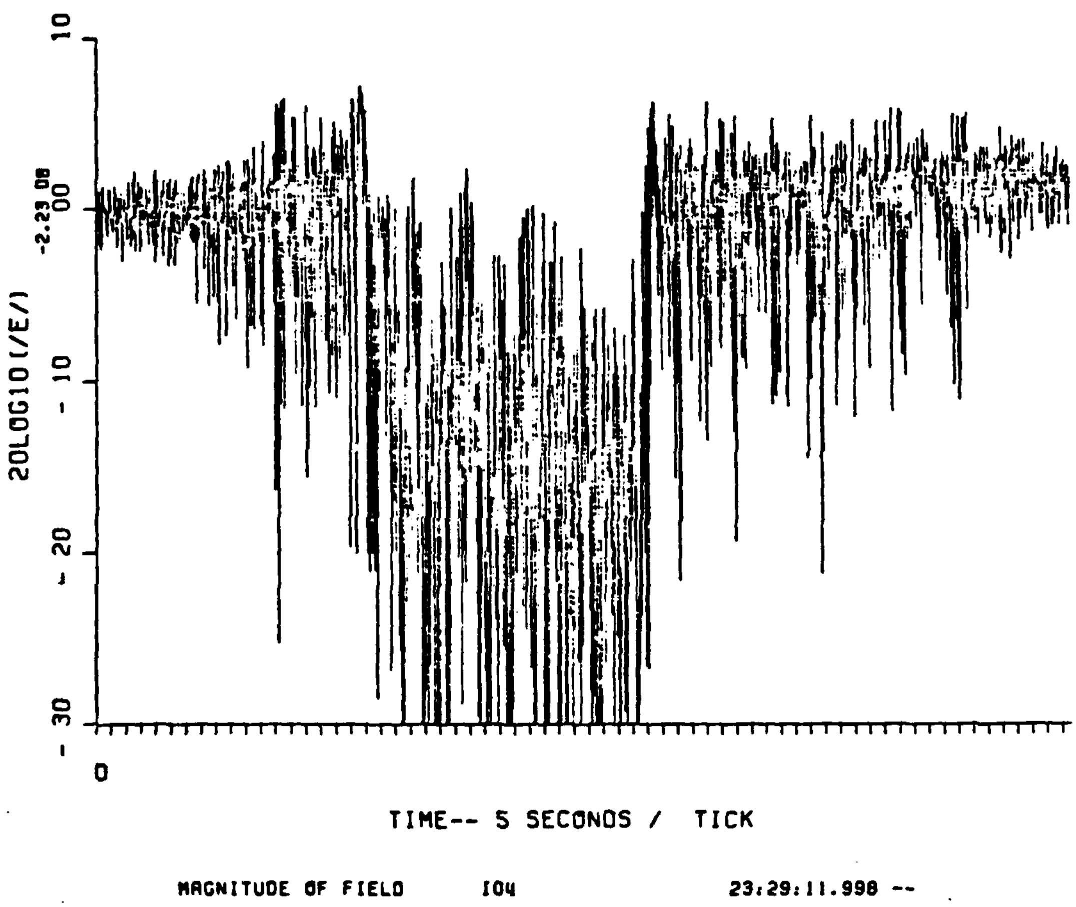

Figure 32. Downlink Fading on IRIS Pass 4, R+18 Minutes

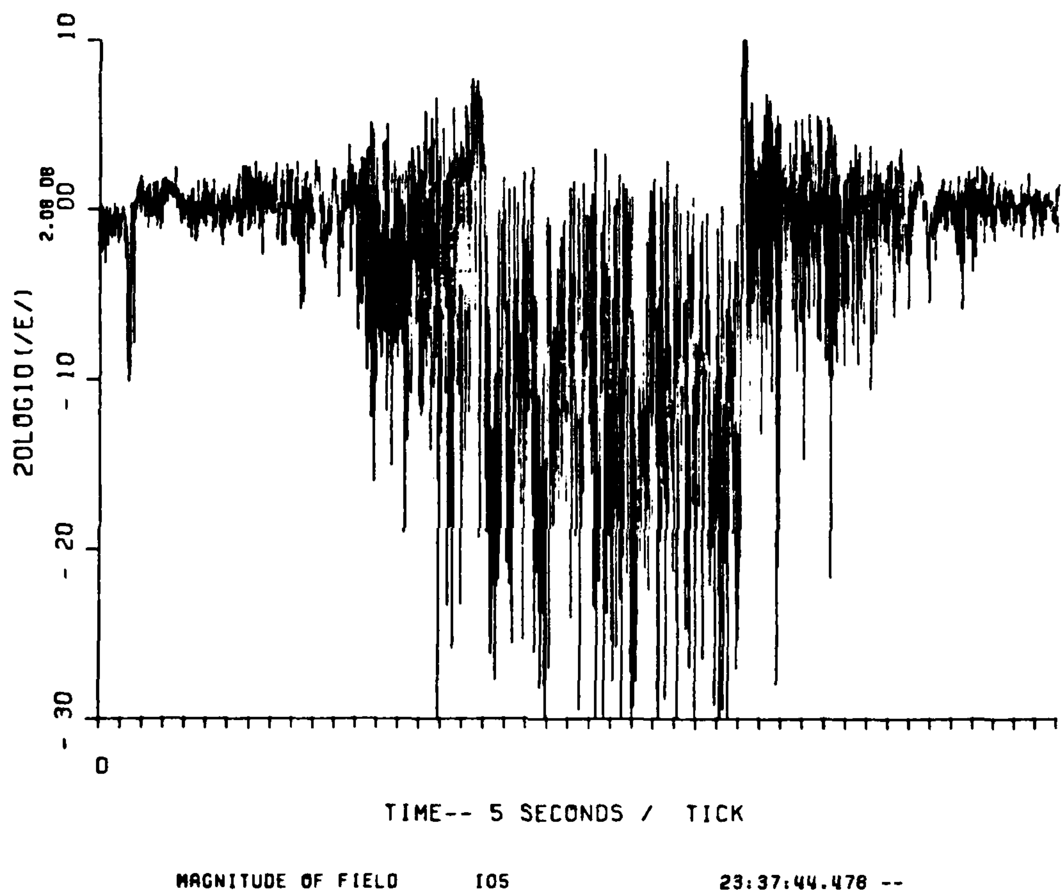

Figure 33. Downlink Fading on IRIS Pass 5, R+26 Minutes

ESTHER. ESTHER Pass 10 was used to originally estimate the probable magnitude of effects expected from the PLACES beacon experiment. The processing window in Figure 32 (Pass 5) did not cover the second fading object evident in the strip chart recording. The first beacon rocket occultation occurred approximately 5 minutes 33 seconds later. Pass 6 (Figure 34) occurred approximately 2 minutes 37 seconds after the first occultation. Pass 7 shown in Figure 35 occurred approximately 5 minutes before the second occultation and showed strong well developed fading along with a shallow defocus. The next pass occurred approximately 4 minutes after the second occultation and shows very little fading activity (see Figure 36). It is possible the aircraft passed north of the true cloud center and thus traversed the striations low on the field lines. As discussed earlier, a quick look at the radar data indicated a large drop in tracking altitude between the first and second occultations. These data need to be examined further to better establish cause and effect before reaching any conclusion. Pass 9, (Figure 37) while reminiscent of late time fading, is more developed than Pass 8. Pass 11 shown in Figure 38 indicates the presence of a well developed cloud once again. The fading on the (developing?) western side of the cloud appears slower than on the eastern side. Pass 12 shown in Figure 39 also shows the slower fading to the west. Figure 40 shows the nature of the fading observed at R+2 hours. Figure 41 shows the last fading seen on IRIS which occurred at R+2 hours 26 minutes.

TEST RESULTS FOR JAN

JAN, the fourth barium release, occurred on 12 December 1980 at 23:13:42. It was released at an altitude of 184.3 kilometers and a

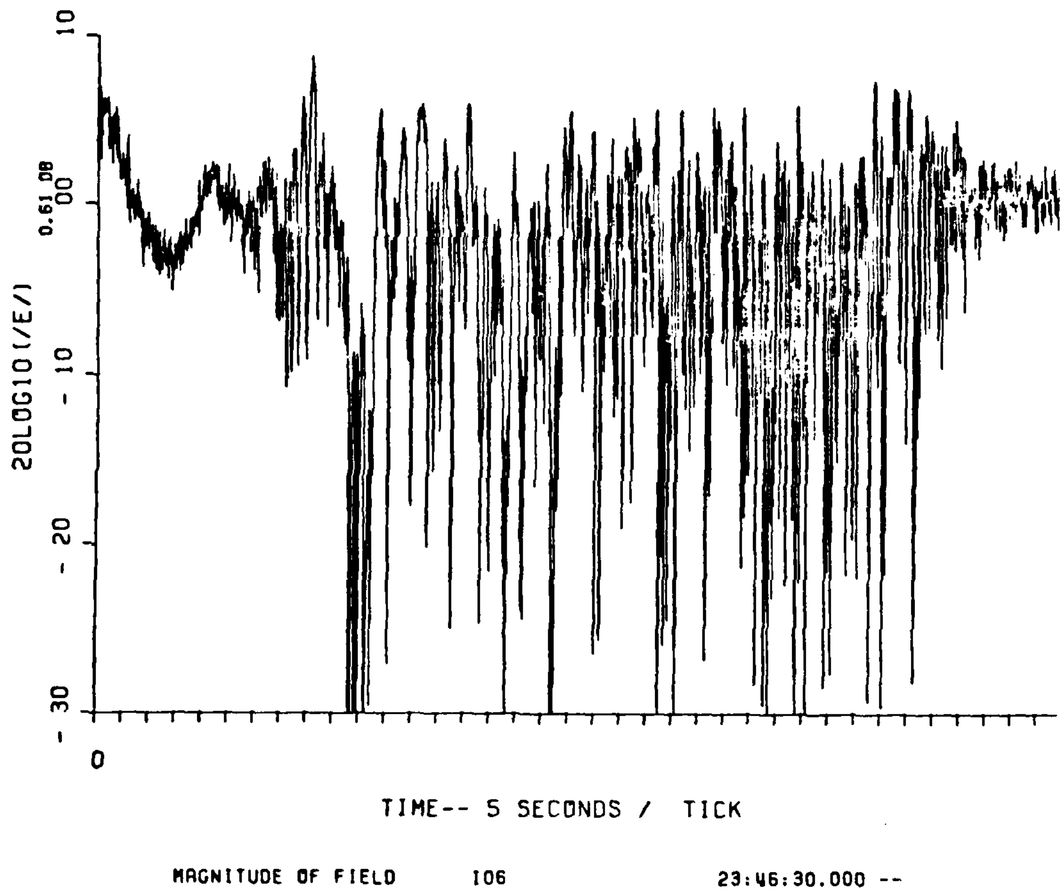

Figure 34. Downlink Fading on IRIS Pass 6, R+34 Minutes

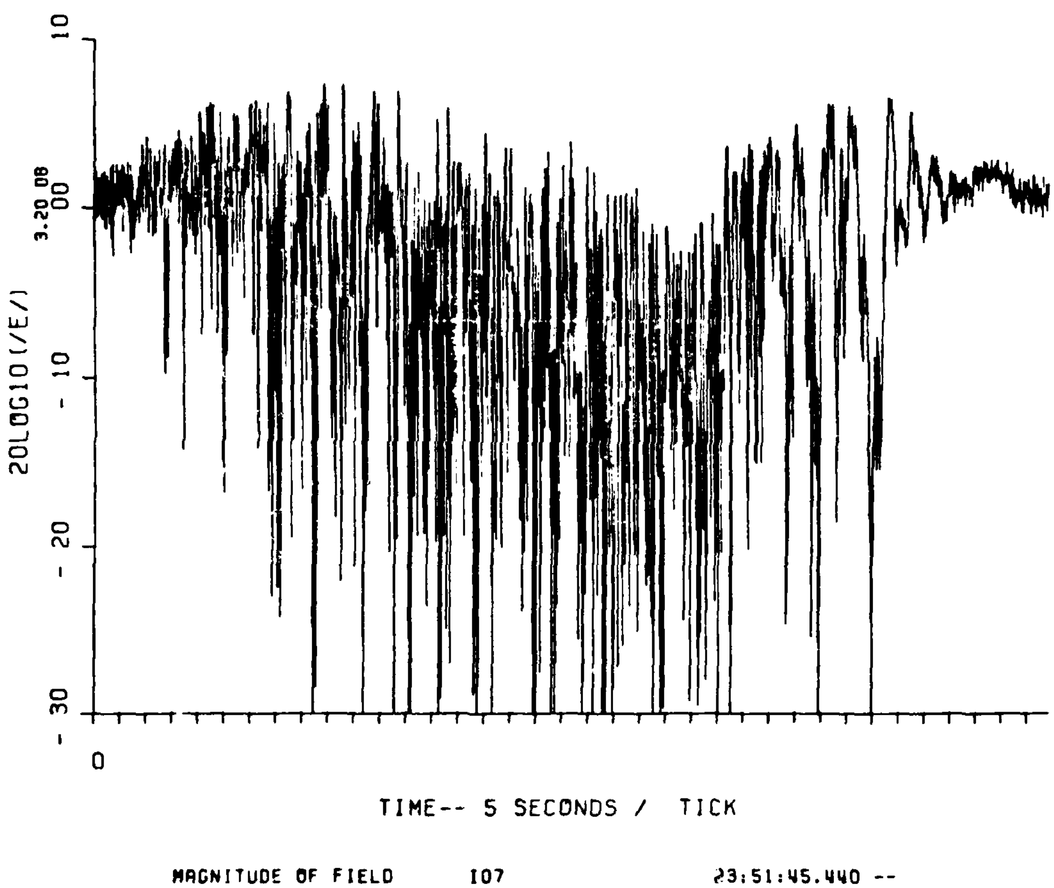

Figure 35. Downlink Fading on IRIS Pass 7, R+39 Minutes

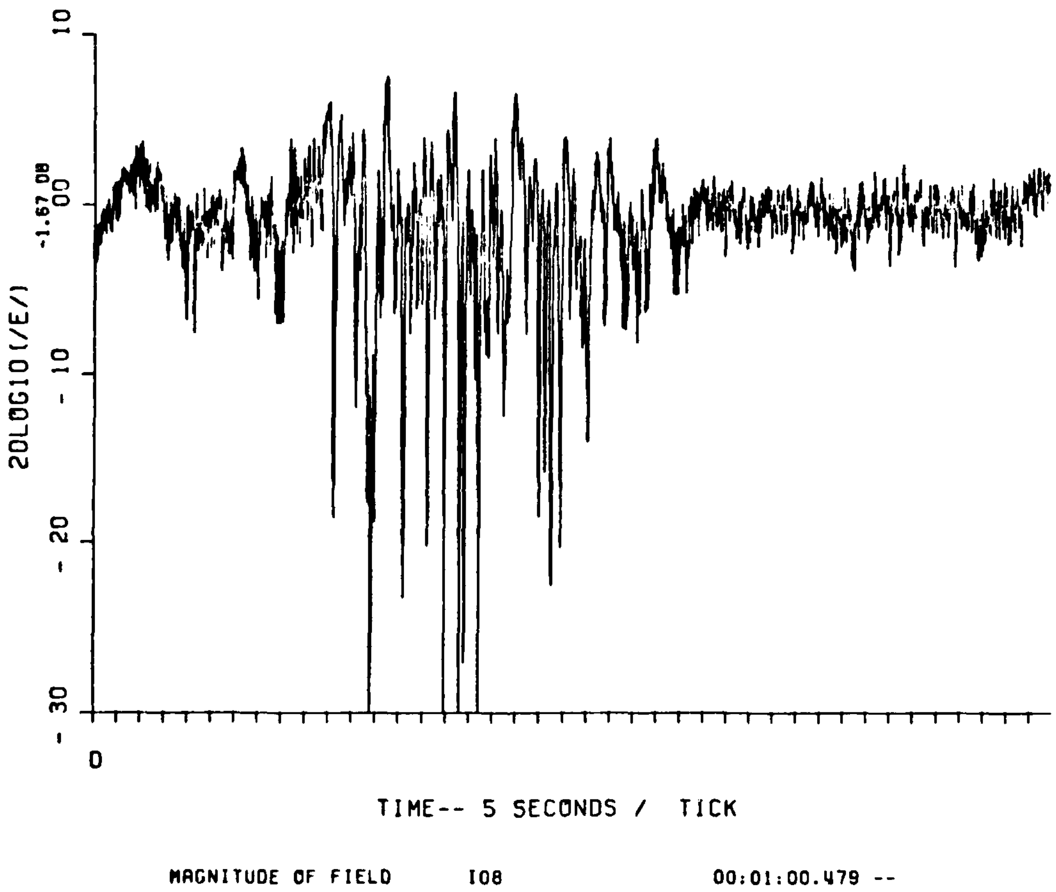

Figure 36. Downlink Fading on IRIS Pass 8, R+49 Minutes

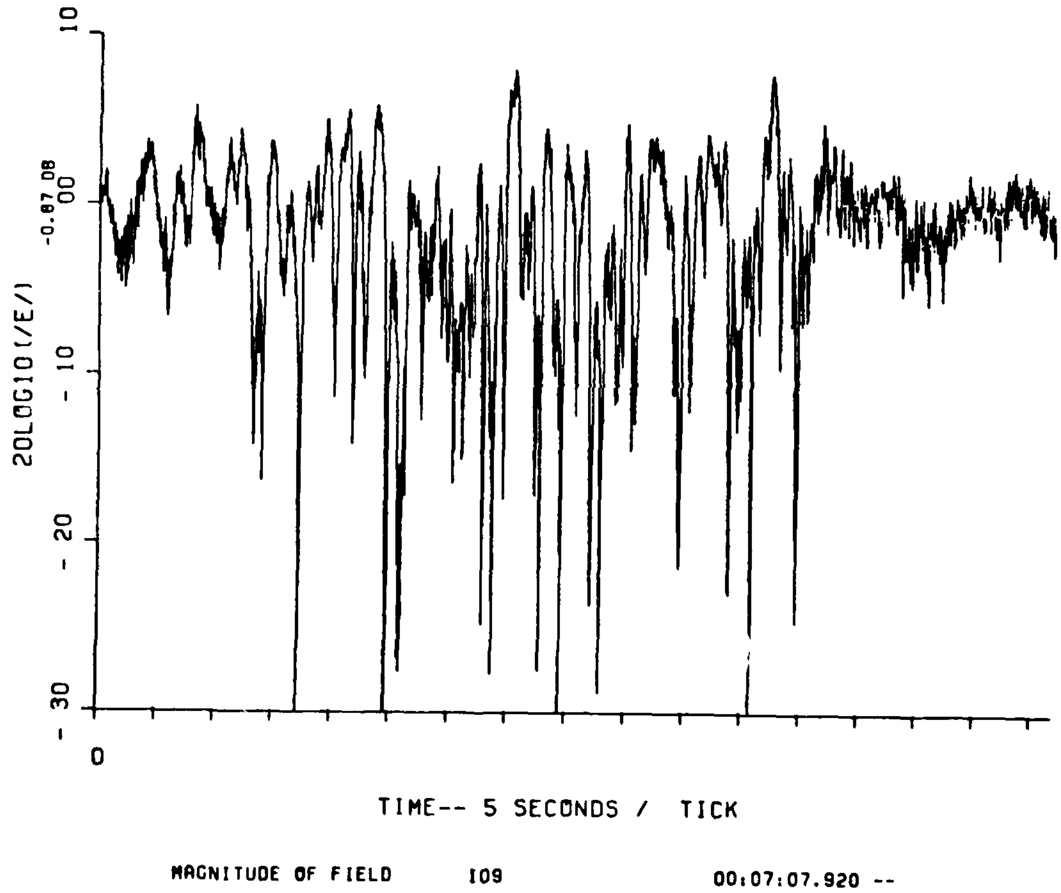

Figure 37. Downlink Fading on IRIS Pass 9, R+1 hour

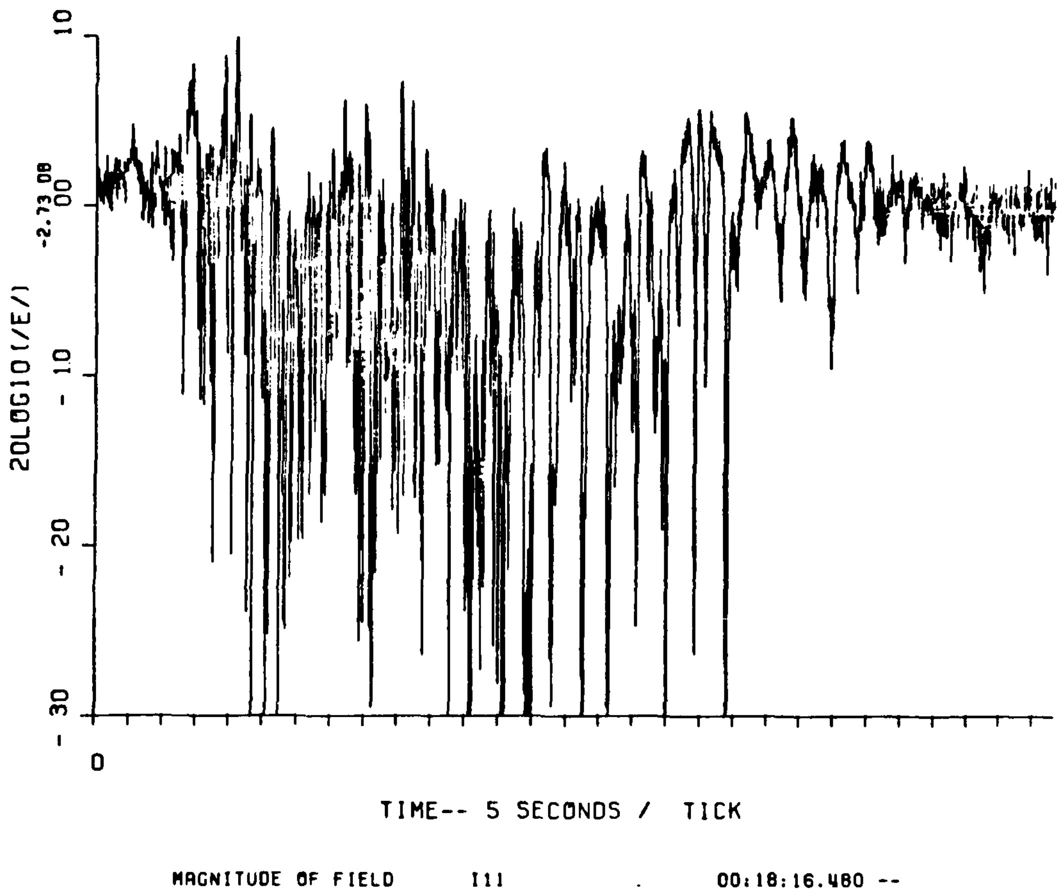

Figure 38. Downlink Fading on IRIS Pass 11, R+1^{h}5^m

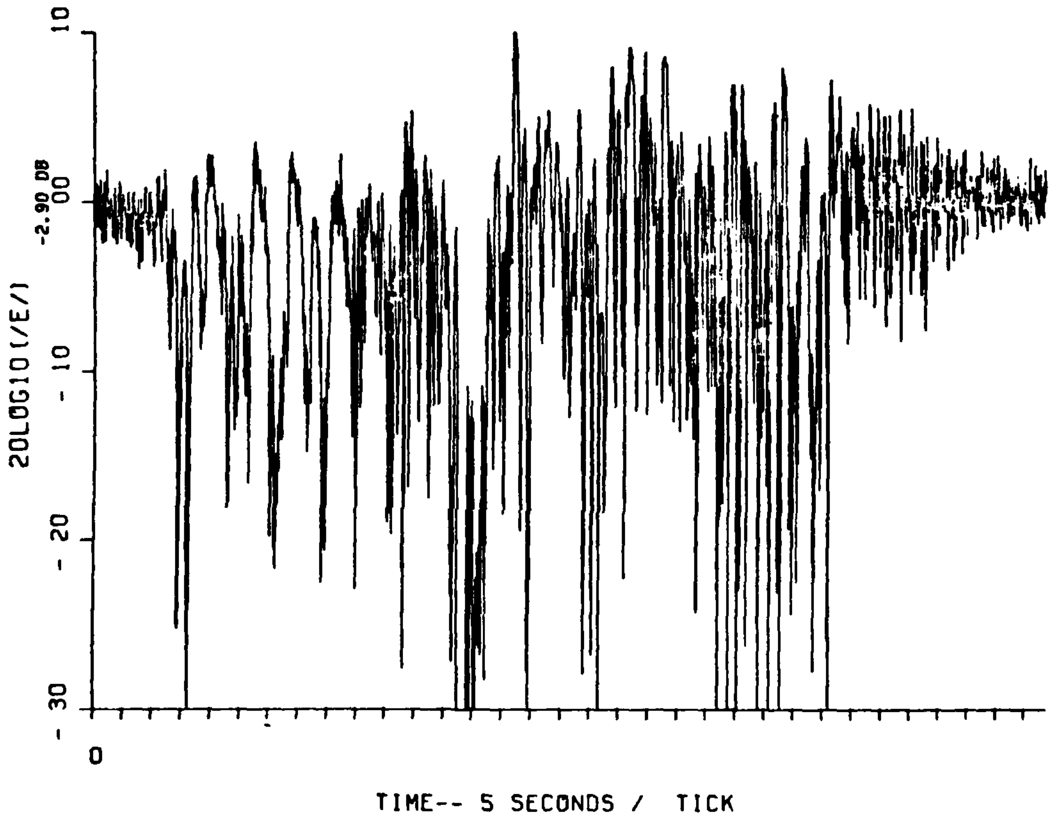

Figure 39. Downlink Fading on IRIS Pass 12, R+1^{h}10^{m}

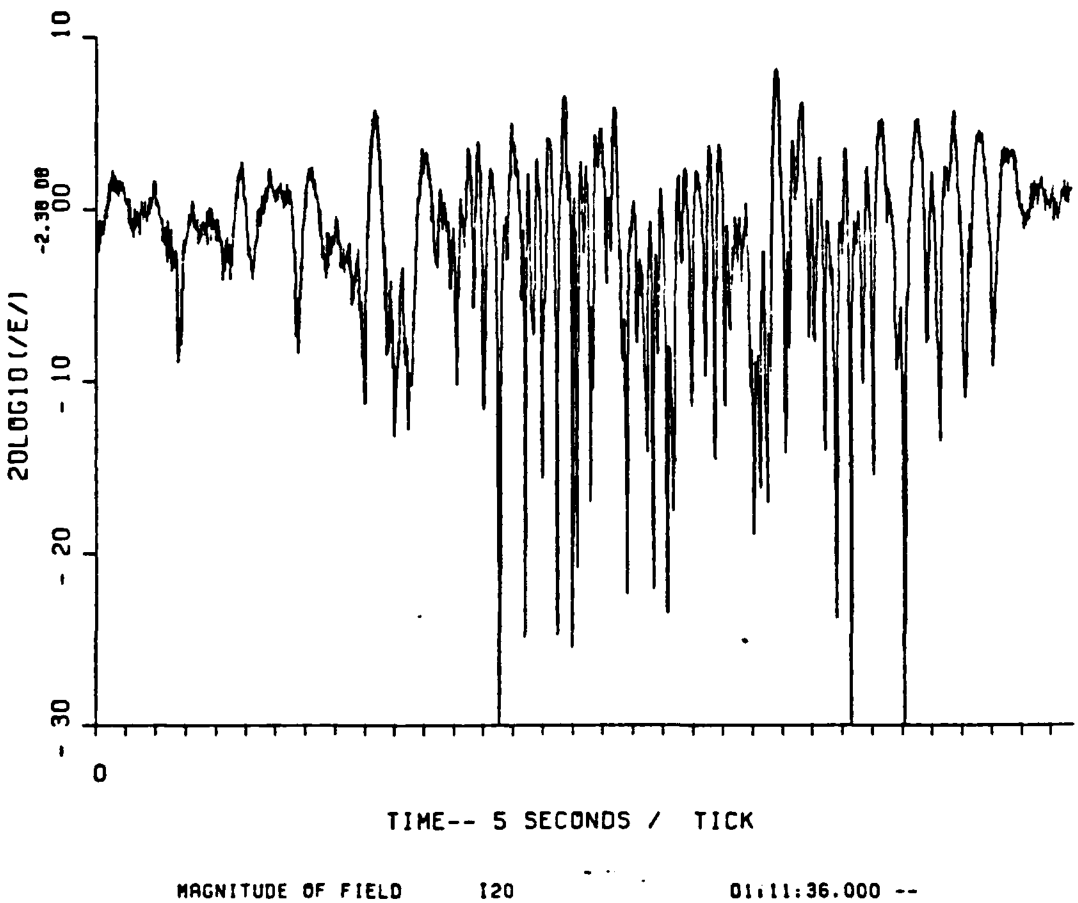

Figure 40. Downlink Fading on IRIS Pass 20, R+2 hours

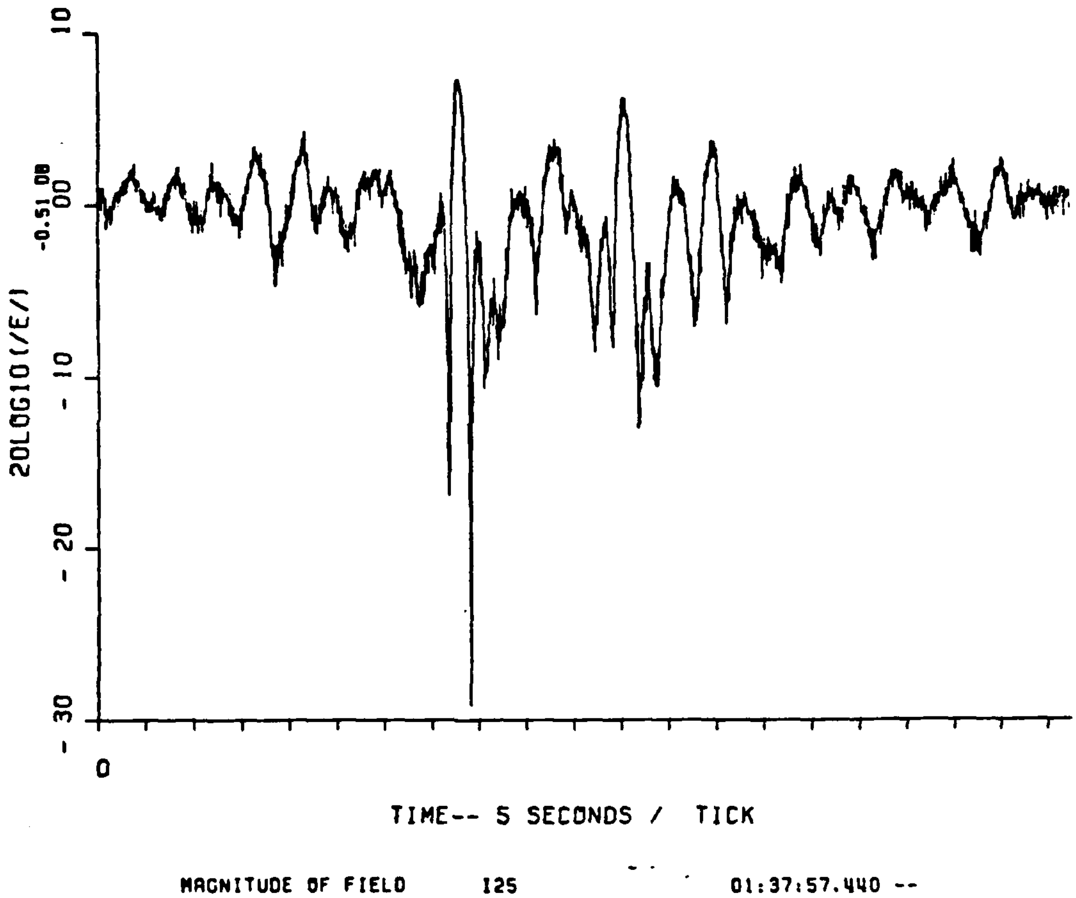

Figure 41. Downlink Fading on IRIS Pass 25, $R+2^h26^m$

latitude and longitude of 29.166°W. This release drifted on an approximate 40° azimuth and then stopped for a few minutes. It then drifted very slowly west for the remainder of the experiment, with its projection ending up about 1 degree west of the initial release projection.

Optics tracking was used until approximately R+48 minutes. It gave reasonably consistent information on the cloud location during this time but the track showed some abrupt changes. Radar tracking was available for the remainder of the experiment, but was inconsistent with the fading observed. The striated portion of the ion cloud was followed using the real time fading displays and the radar tracking of the aircraft. Plots of the available cloud tracking data and the aircraft ground track are given in Figures 42 and 43. The aircraft ground track during each hour is shown in Figures 44, 45 and 46 along with periods of strong fading.

A total of 35 passes were made ending at R+3 hours 33 minutes. A summary of these passes is contained in Table 11. Diffraction ringing with large -15 dB defocus was seen during the first three passes. Strong fading was present for all 18 passes between R+24 minutes and R+1 hour 2 minutes. Very good data was received during this time. Moderate to strong fading was present in four of the next eight passes ending at R+2 hours 44 minutes. Fading was seen as late as R+2 hours 54 minutes.

Uplink and downlink data was received for all passes. K-band lock was not lost during this release. Overall, it is believed that the highest quality data was obtained during JAN.

No beacon rockets were launched during this release. A 100 kilometer solution could not be used due to the close proximity of shipping traffic. A computer hardware failure delayed processing of a 40 kilometer solution

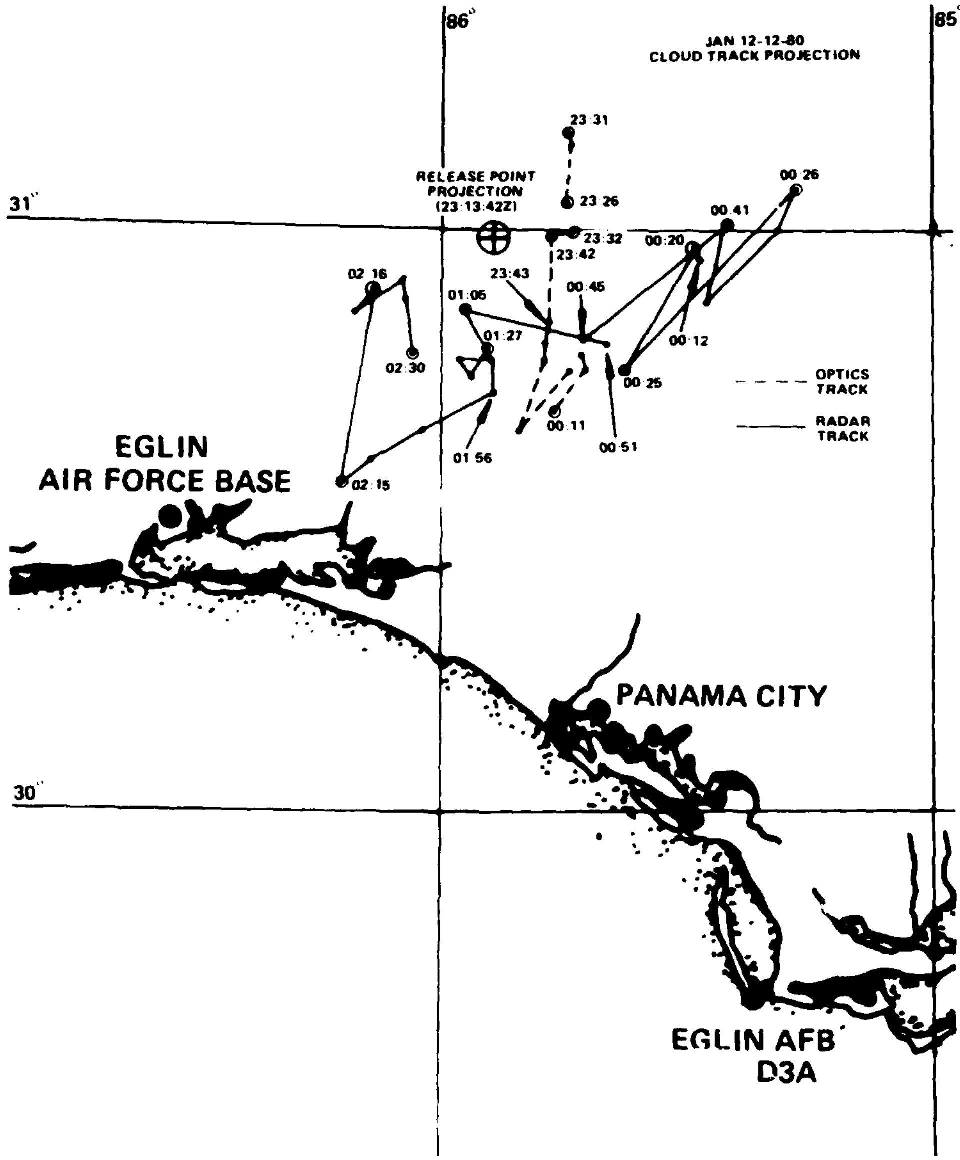

Figure 42. Ion Cloud Track Projection for JAN

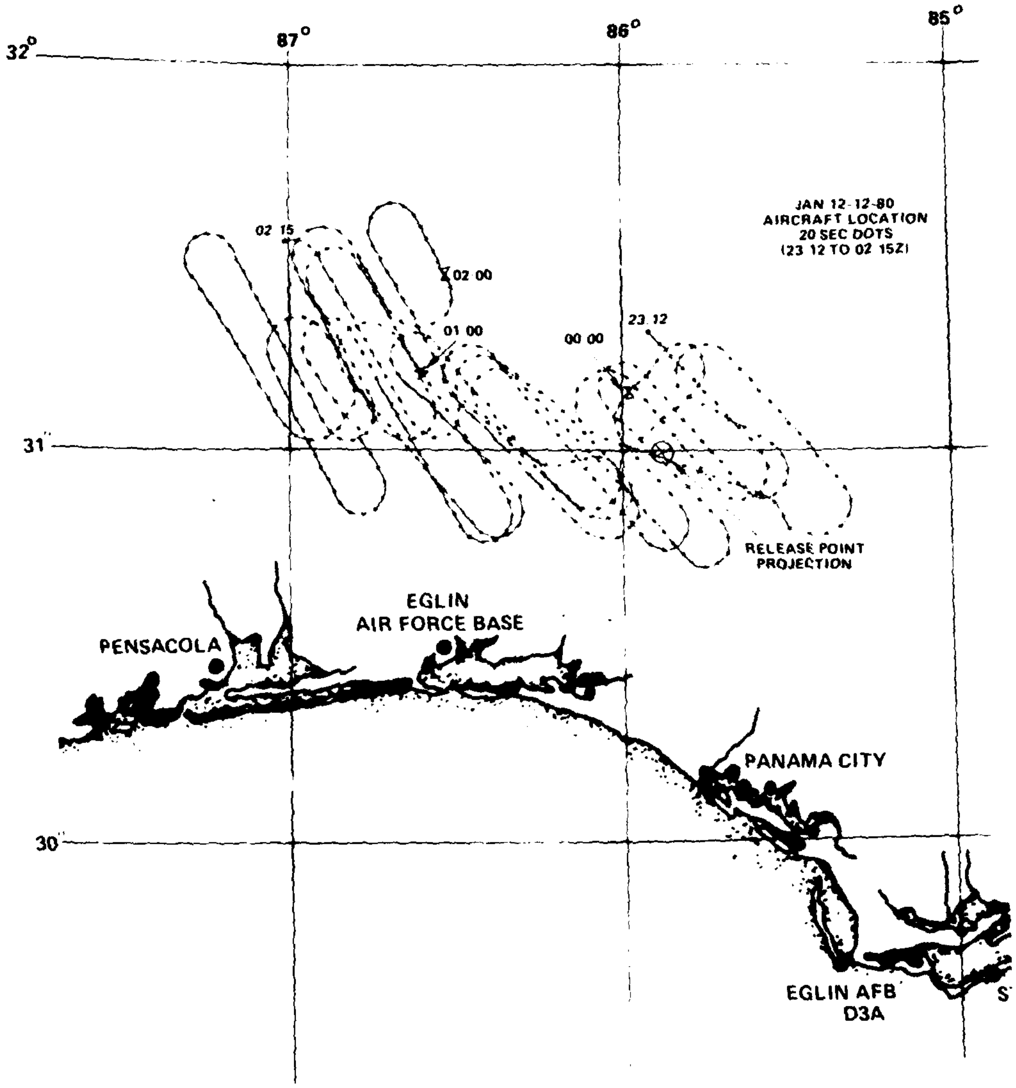

Figure 43. Aircraft Ground Track for JAN

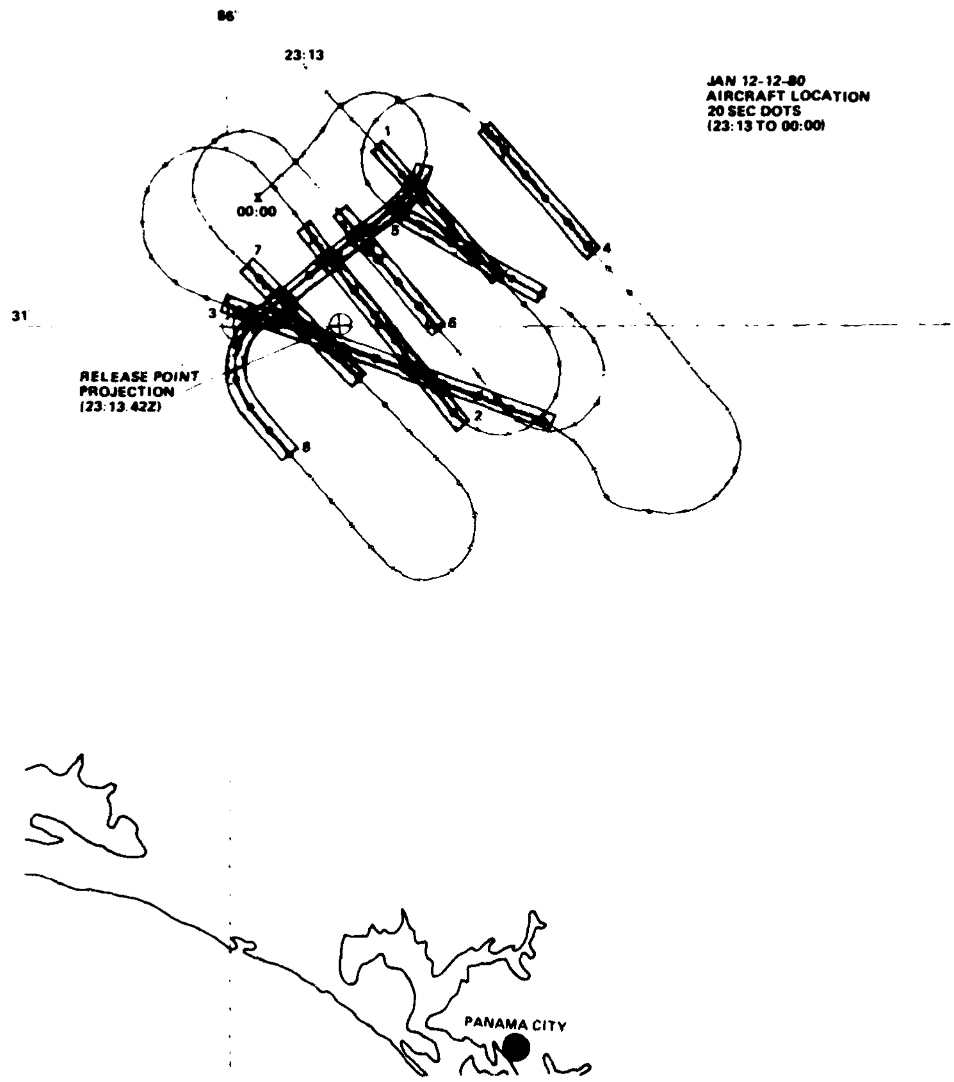

Figure 44. Aircraft Ground Track for JAN from 23:13 to 00:00Z. Periods of Deep Fading are Shaded

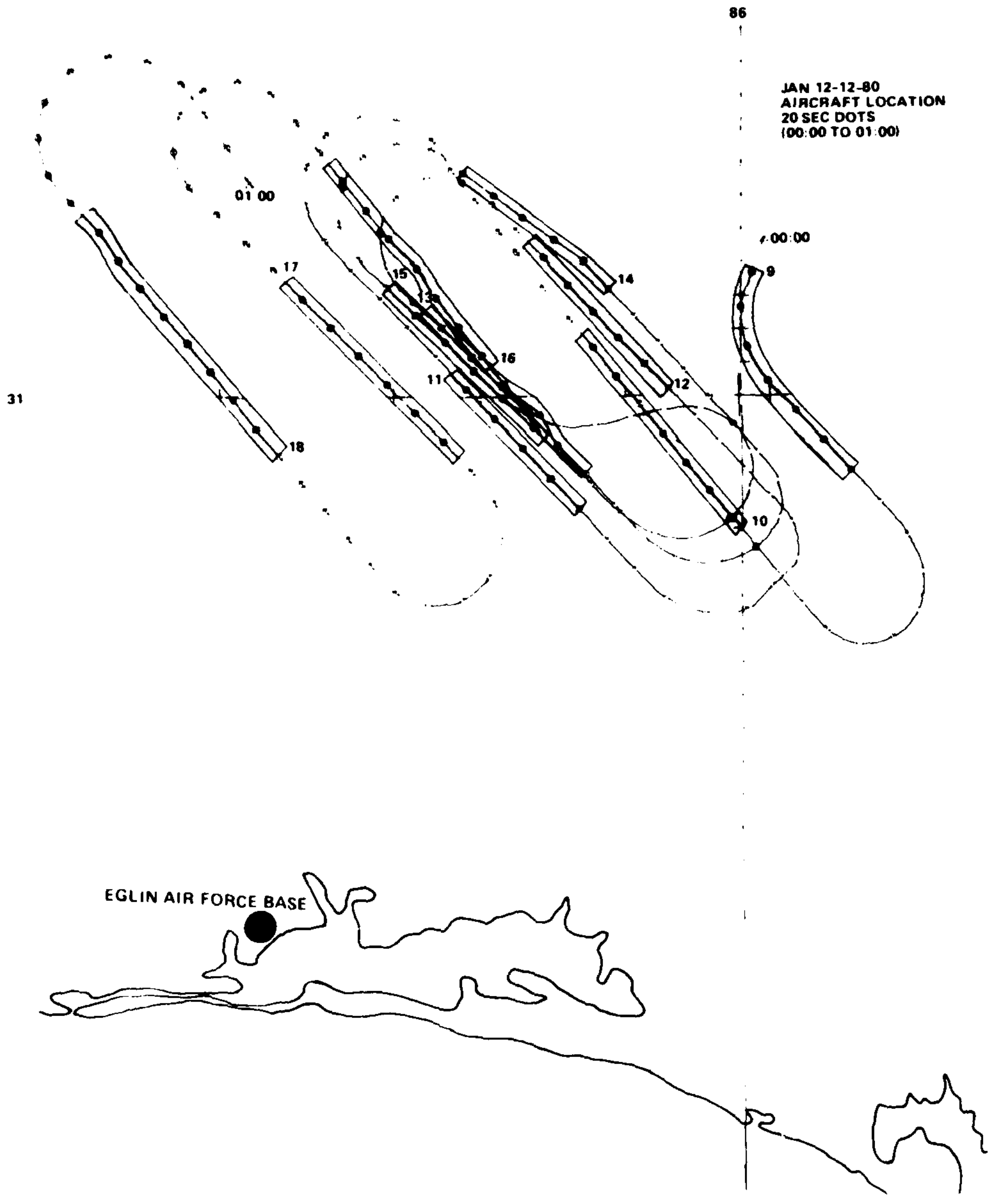

Figure 45. Aircraft Ground Track for JAN from 00:00 to 01:00Z. Periods of Deep Fading are Shaded

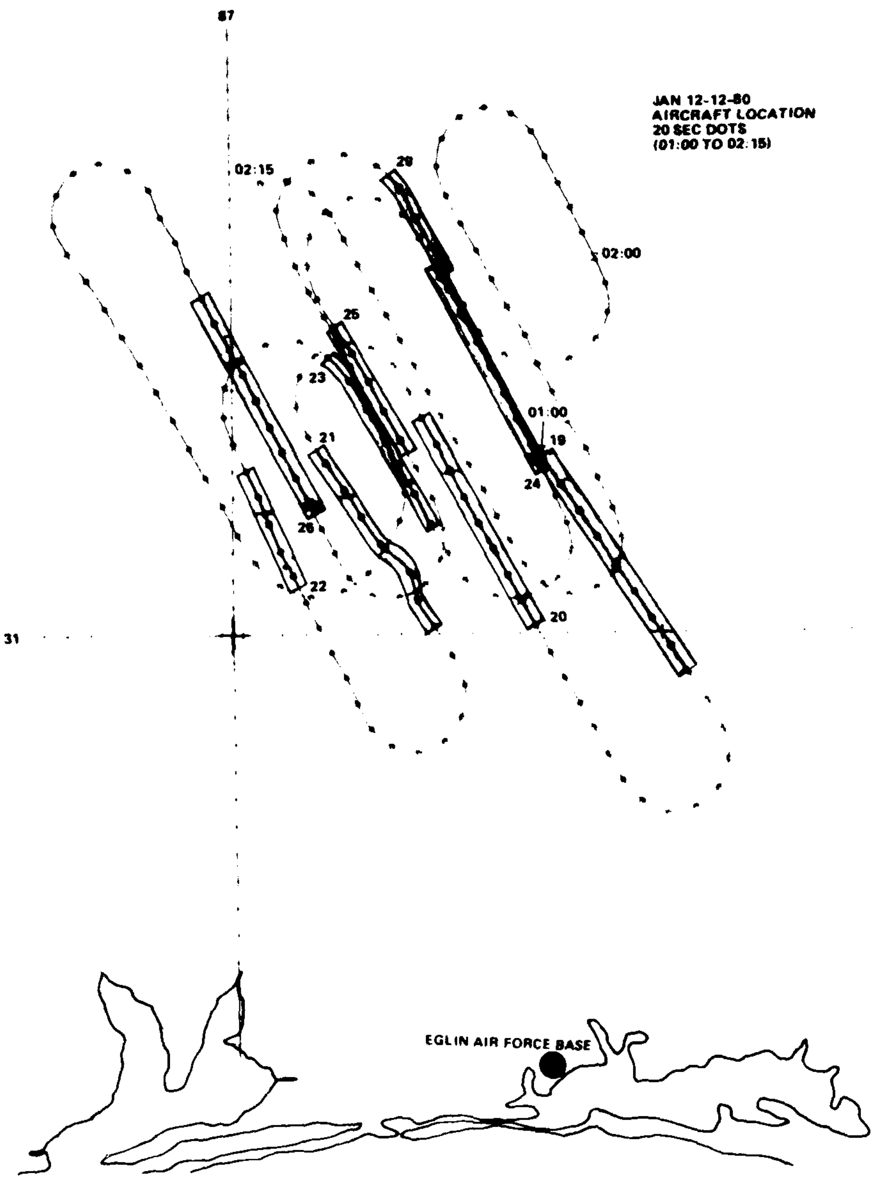

Figure 46. Aircraft Ground Track for JAN from 01:00 to 02:15Z. Periods of Deep Fading are Shaded

TABLE 11

AIRCRAFT DATA SUMMARY FOR JAN

Pass No.	Time	K-Lock	Comments
1	23:14:00-23:45:40	Yes	Moderate diffraction ringing
2	23:18:10-23:20:50		Diffraction ringing with large ~15 dB defocus
3	23:24:30-23:27:30		Diffraction ringing with large ~15 dB defocus
4	23:32:50-23:34:40		Strong fading, but short
5	23:37:00-23:38:40		Strong fading
6	23:42:20-23:44:00		Strong fading
7	23:47:10-23:48:40		Strong fading
8	23:53:20-23:57:00		Strong fading
9	00:00:20-00:02:20		Strong fading
10	00:05:50-00:08:10		Strong fading
11	00:13:50-00:15:20		Strong fading
12	00:19:30-00:21:30		Strong fading
13	00:24:10-00:26:00		Strong fading
14	00:30:40-00:32:20		Strong fading
15	00:34:40-00:36:30		Strong fading
16	00:41:40-00:44:10		Strong fading
17	00:47:50-00:49:50		Strong fading
18	00:53:40-00:56:30		Strong fading
19	01:00:00-01:02:40		Strong fading
20	01:07:20-01:10:00		Strong fading
21	01:12:50-01:15:00		Strong fading
22	01:19:10-01:20:40		Weak fading
23	01:23:00-01:25:00		Strong fading
24	01:28:00-01:30:40		Moderate fading
25	01:33:40-01:35:10		Moderate fading
26	01:38:30-01:41:20		Weak fading, large focus
27	01:45:30-01:47:30		No fading

AD-A118 975 ESL INC SUNNYVALE CA F/G 20/14
PLACES AIRBORNE EXPERIMENT.(U)
MAY 82 R L SWANSON, A L JOHNSON, J MARSHALL DNA001-80-C-0090
UNCLASSIFIED AFWAL-TR-81-1250 NL

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TABLE 11

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Pass No.	Time	K-Lock	Comments
28	01:51:50-01:53:30	Yes	Weak fading
29	01:55:30-01:57:00		Strong fading
30	01:59:40-02:01:20		No fading
31	02:03:20-02:07:20		Weak fading
32	02:09:30-02:14:00		No fading
33	02:20:00-02:25:00		No fading
34	02:30:30-02:37:00		No fading
35	02:39:00-02:46:50		No fading

and the cloud was outside range safety limits by the time the computer came back on line at R+36 minutes. A probe rocket was successfully launched however. (Szuszczewicz et al, 1981)

Samples of processed amplitude and phase plots for JAN are given in Figures 47 and 63. They show the full progression of cloud development from diffraction ringing to strong deep fading, to the eventual loss of track. These figures have been processed from the uplink tone data.

The strong diffraction ringing that was noted about 1 minute after release on the first pass is shown in Figure 47. This developed into a large defocus of -10 dB by R+6 minutes as shown in Figures 48 and 49. No structuring is evident during this pass. Again the alignment of the ion cloud stretch direction with the propagation path may influence the manifestation of the large defocus. A large -20 dB defocus with some developing structure is shown in Figures 50 and 51. Passes 7 and 12 in Figures 52 through 55 show the continuing development of the striation structuring effects. The fading at 1 hour 30 minutes and at 2 hours after release is shown in Figures 56 through 59. A R+2 hours 15 minutes what appears to be a diffusion of the striations away from the main cloud is shown in Figures 60 and 61. The last significant fading seen during JAN at R+2 hours 42 minutes is shown in Figures 62 and 63.

The integrated electron content decreased considerably over the course of the JAN release as one would expect. This is evident in the total phase wind-up of each subsequent aircraft pass. The phase wind-up varied from 109π radians in Pass 2 to 5π radians in Pass 29 as shown in the preceeding figures. The integrated electron content is shown plotted for JAN in Figure 64.

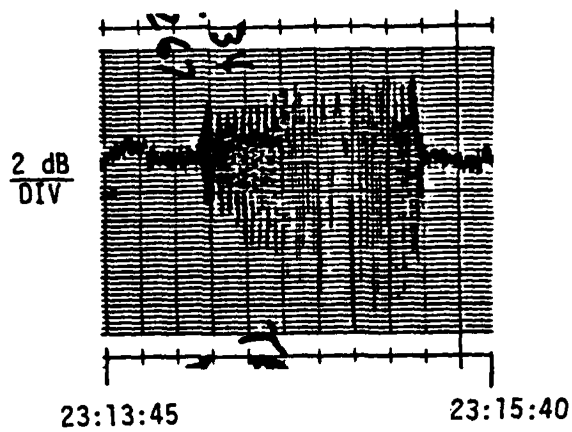

Figure 47. Downlink Fading on JAN Pass1, R+1 Minute

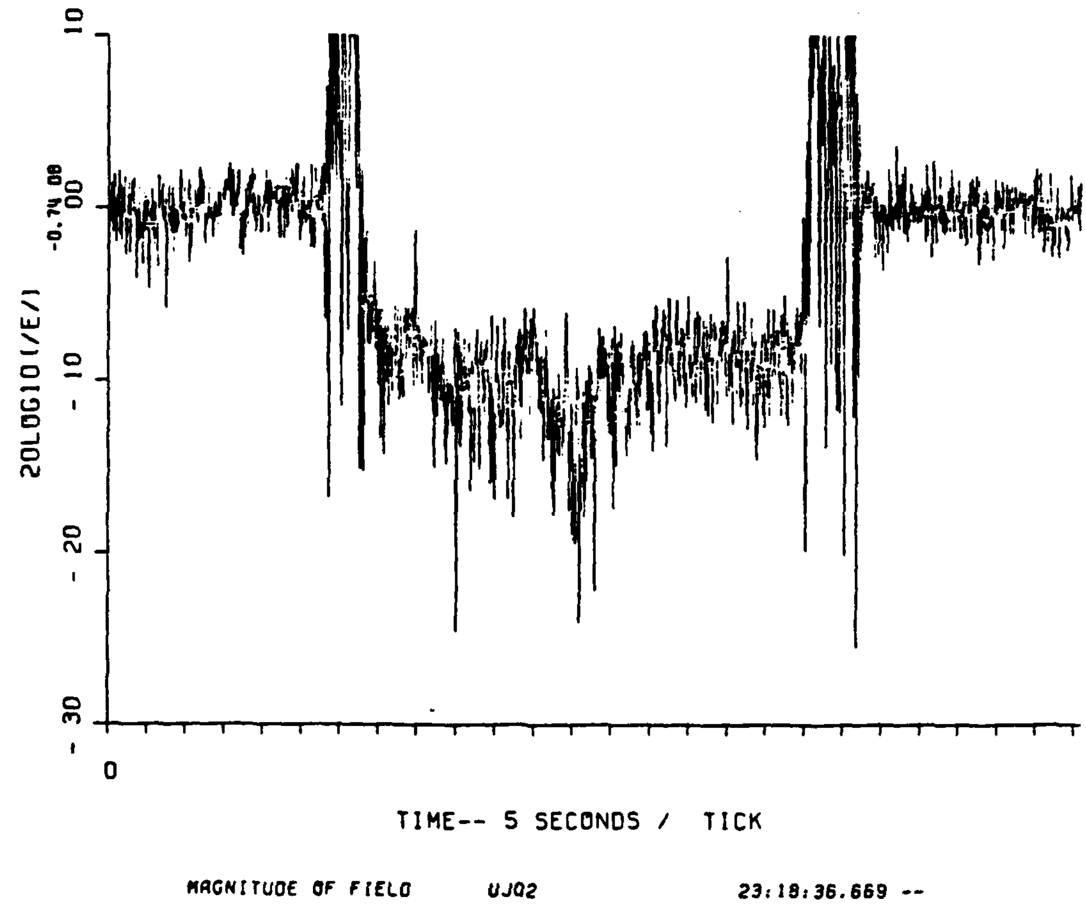

Figure 49. Uplink Fading on JAN Pass, R+6 Minutes

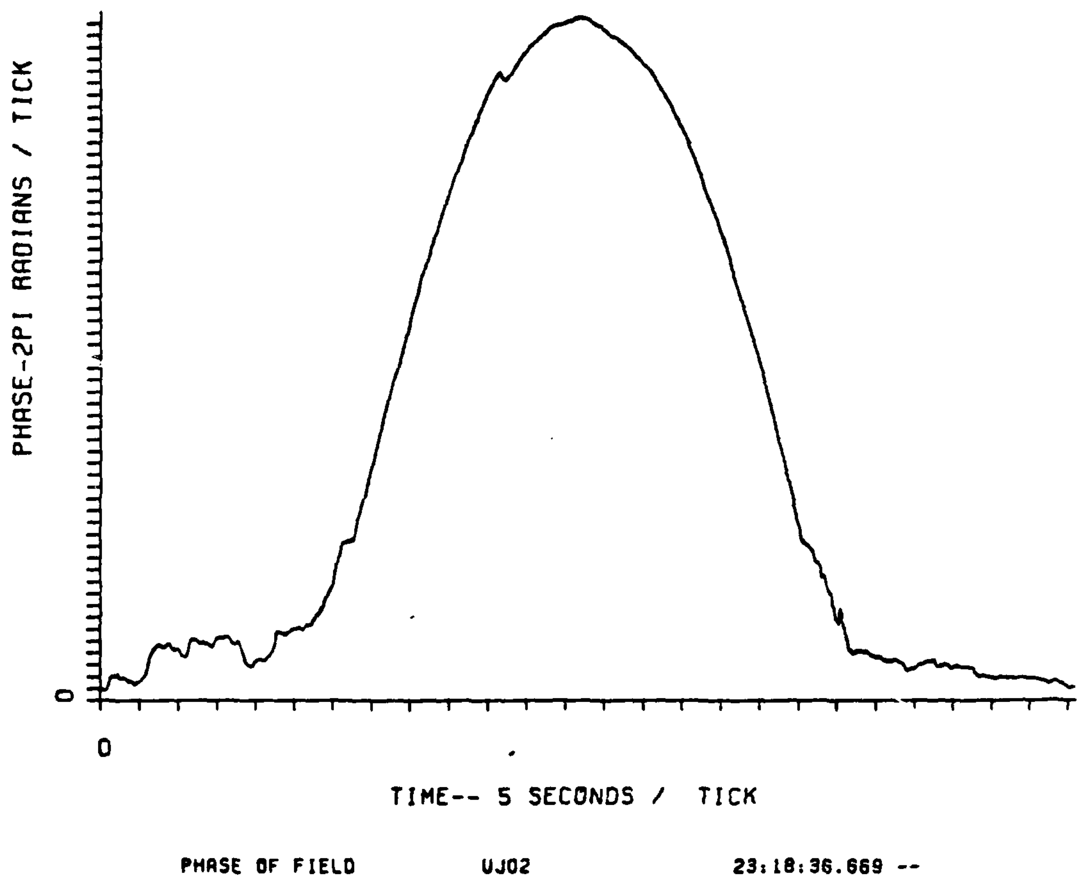

Figure 49. Uplink Phase Effects on JAN Pass 2, R+6 Minutes

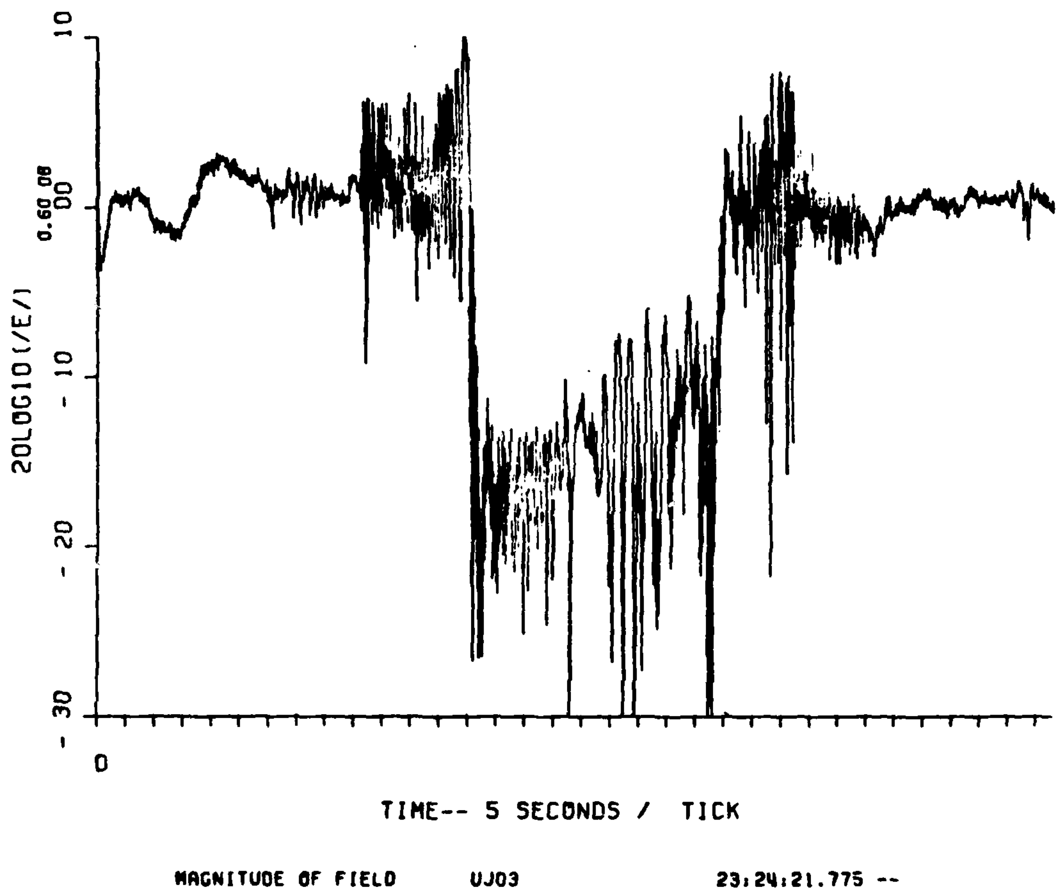

Figure 50. Uplink Fading on JAN Pass 3, R+13 Minutes

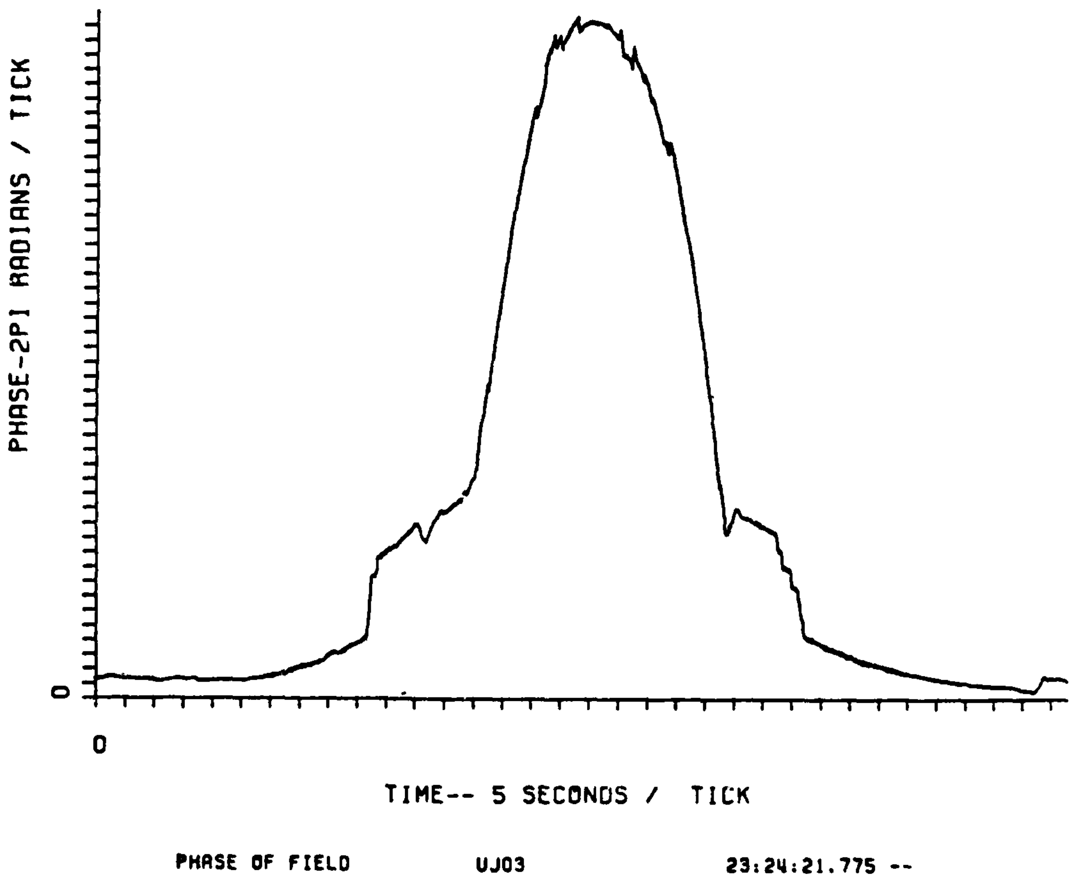

Figure 51. Uplink Phase Effects on JAN Pass 3, R+13 Minutes

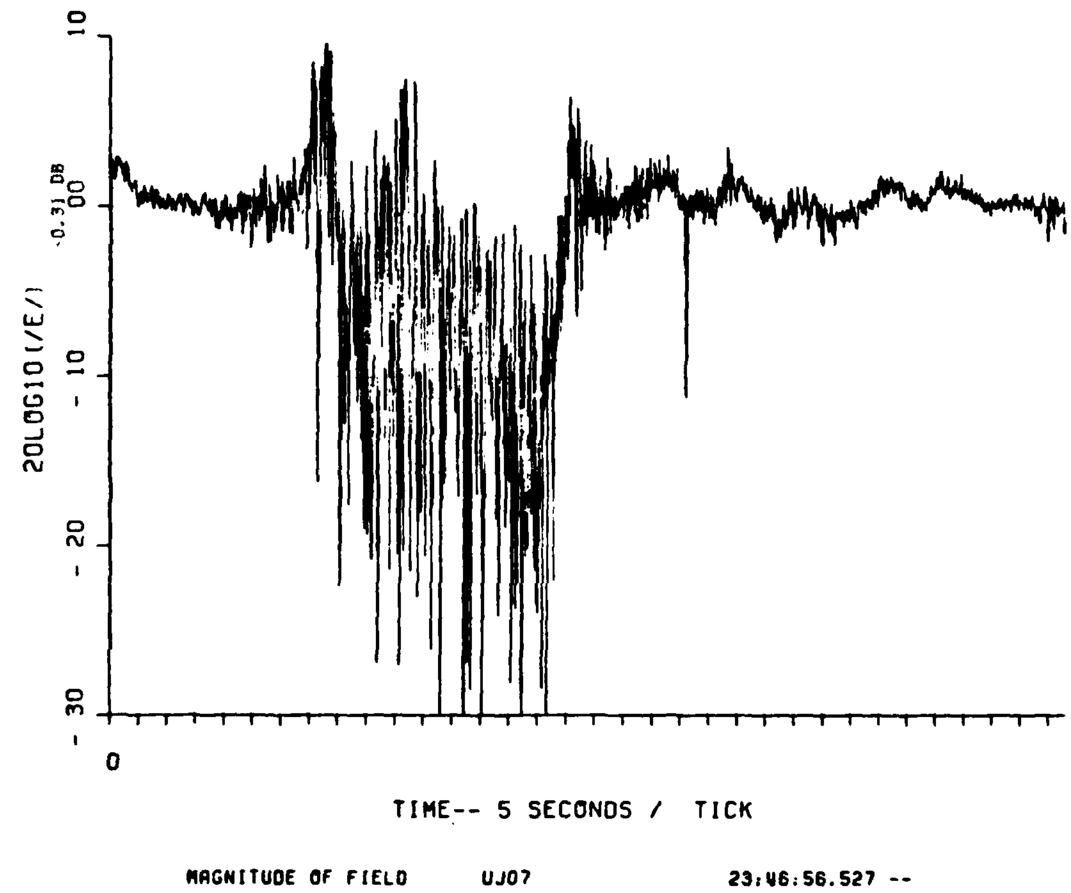

Figure 52. Uplink Fading on JAN Pass 7, R+30 Minutes

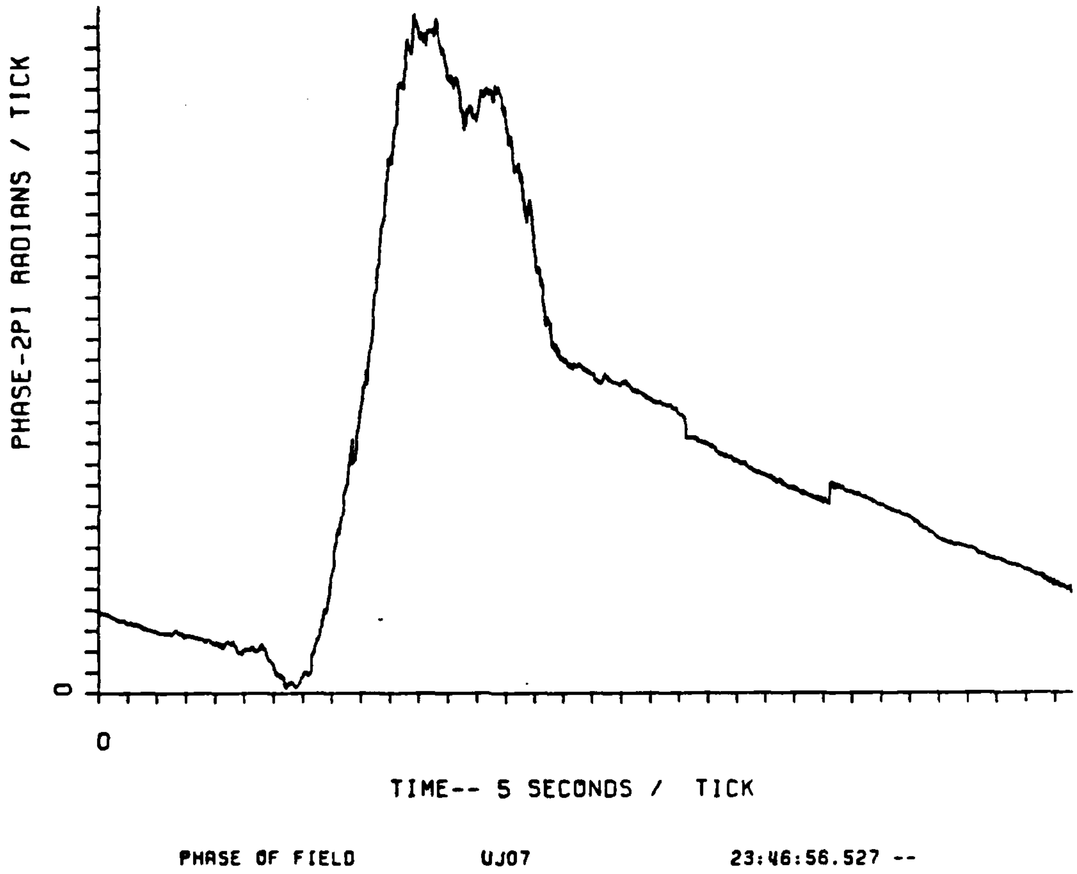

Figure 53. Uplink Phase Effects on JAN Pass 7, R+30 Minutes

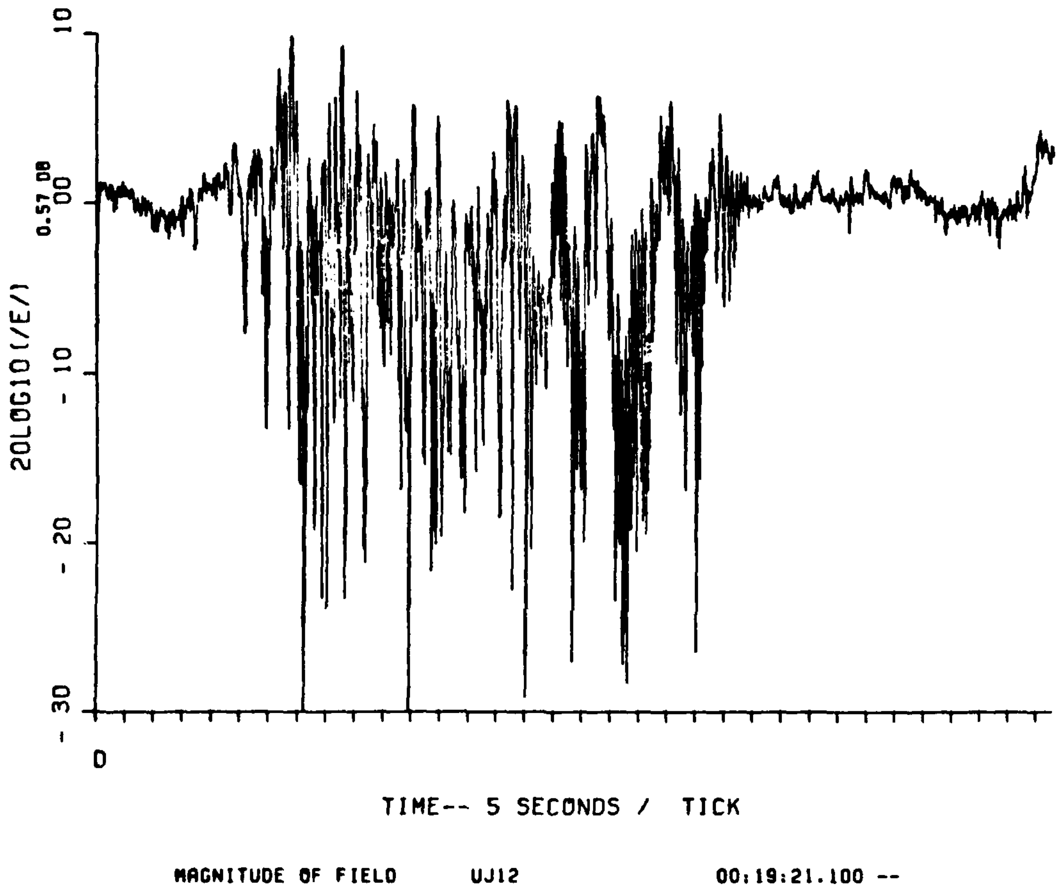

Figure 59. Uplink Fading on JAN Pass 12, R+1 Hour

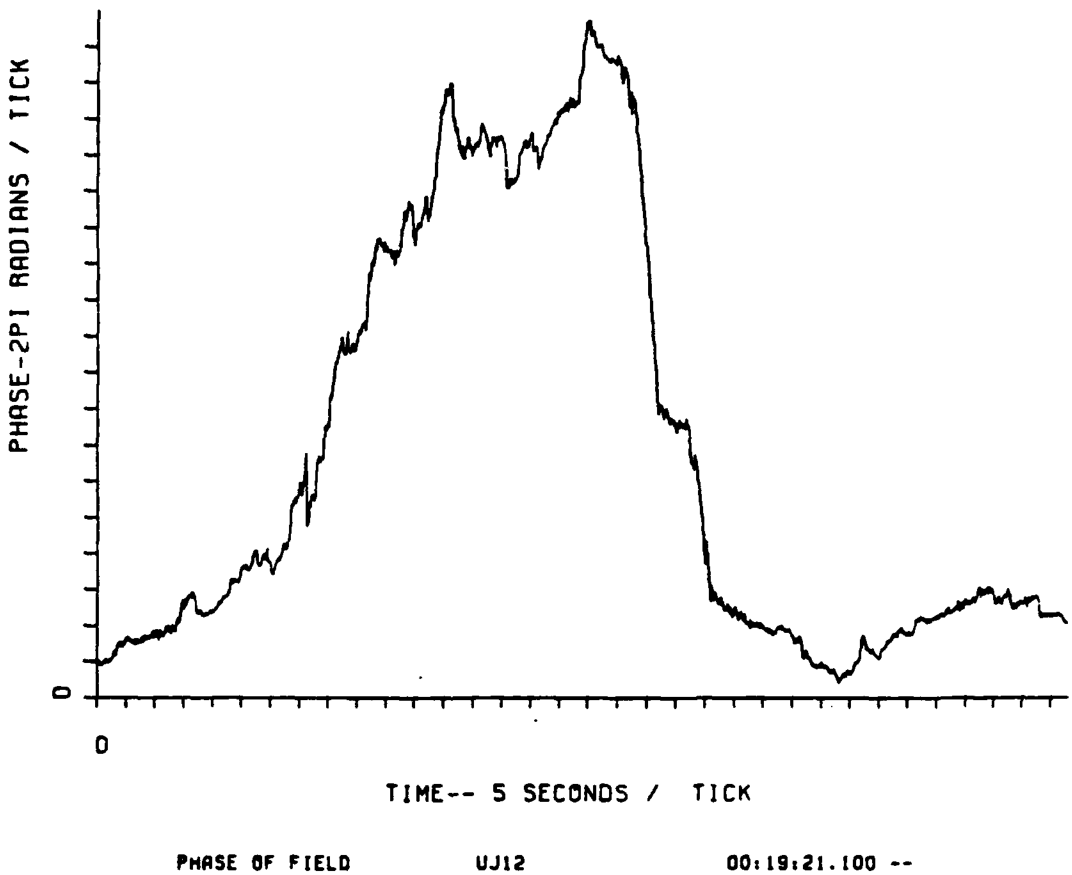

Figure 51. Uplink Phase Effects on JAN Pass 12, R+1 Hour

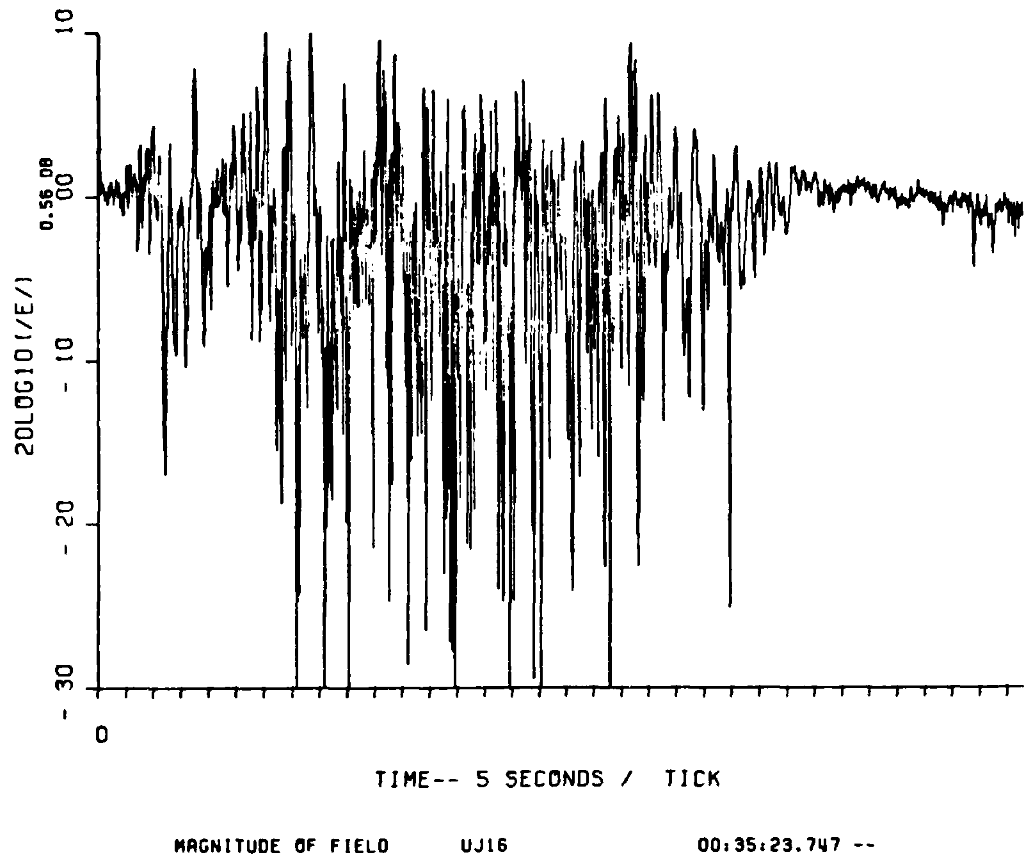

Figure 56. Uplink Fading on JAN Pass 16, R+1^{h}30^{m}

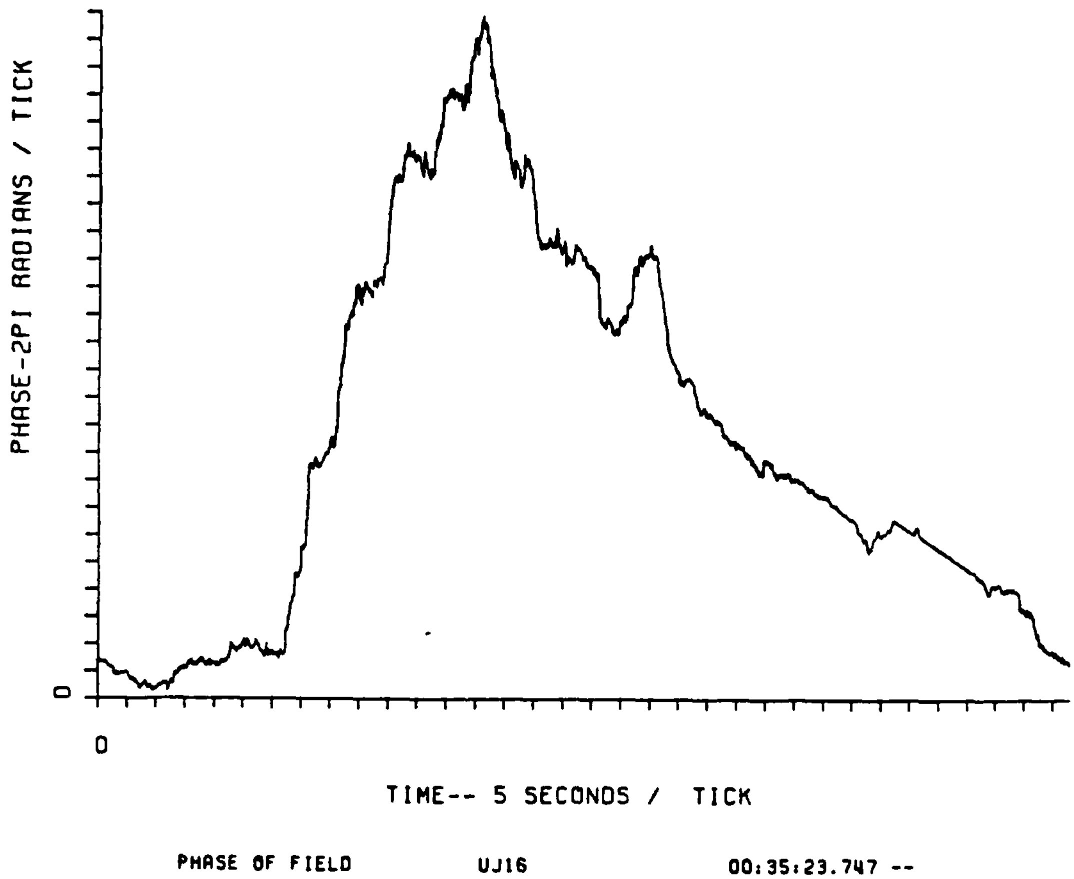

Figure 57. Uplink Phase Effects on JAN Pass 16, R+1^{h}30^m

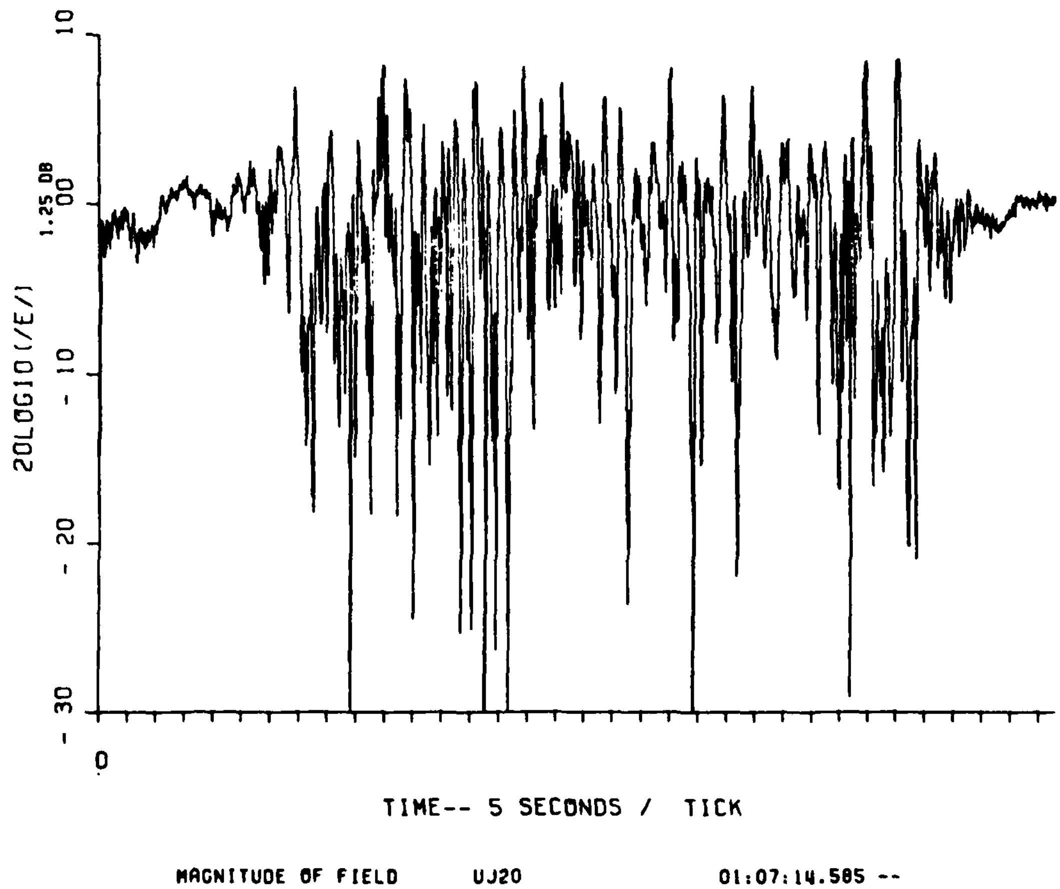

Figure 58. Uplink Fading on JAN Pass 20, R+2 Hours

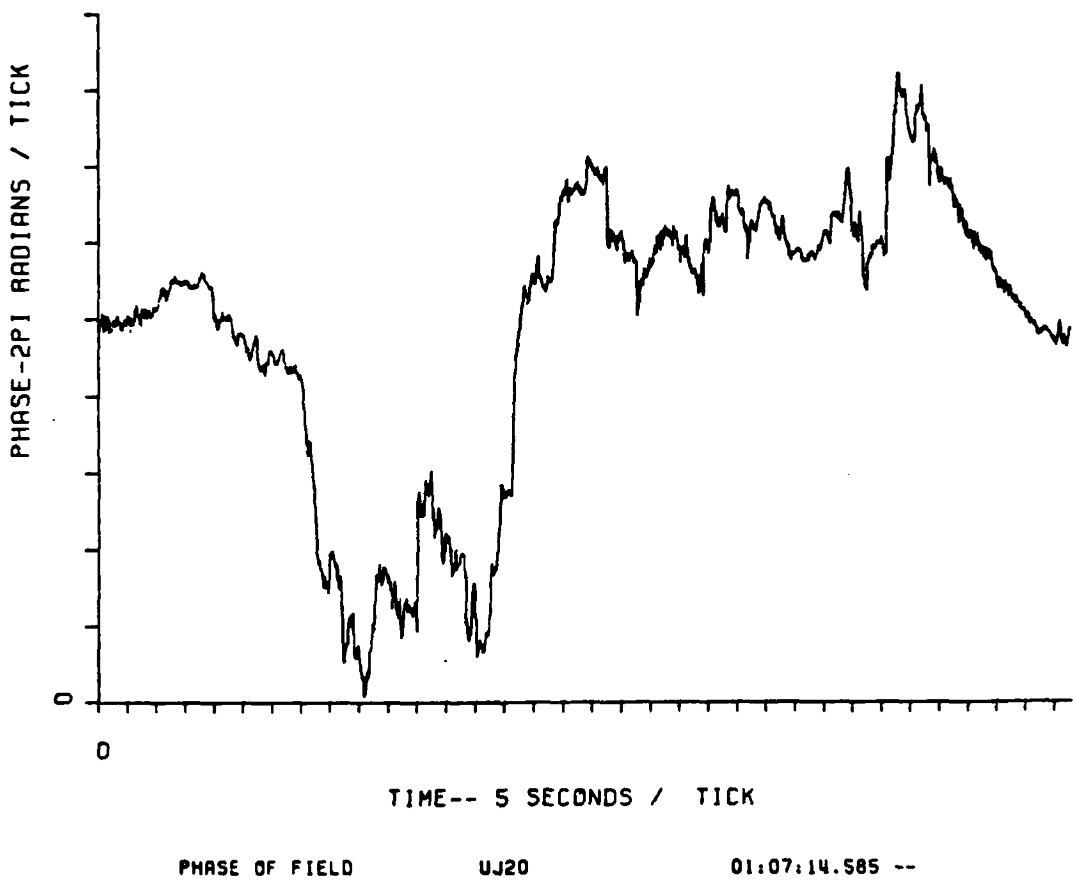

Figure 59. Uplink Phase Effects on JAN Pass 20, R+2 Hours

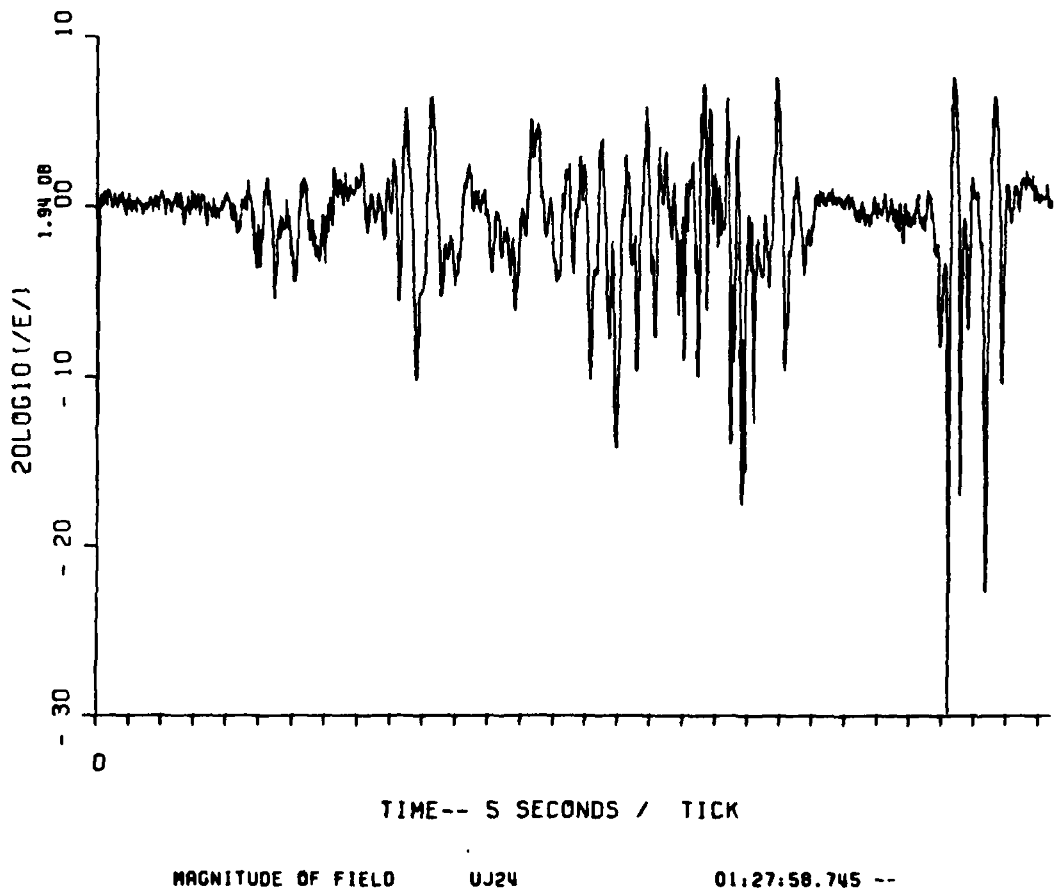

Figure 60. Uplink Fading on JAN Pass 24, $R+2^h15^m$

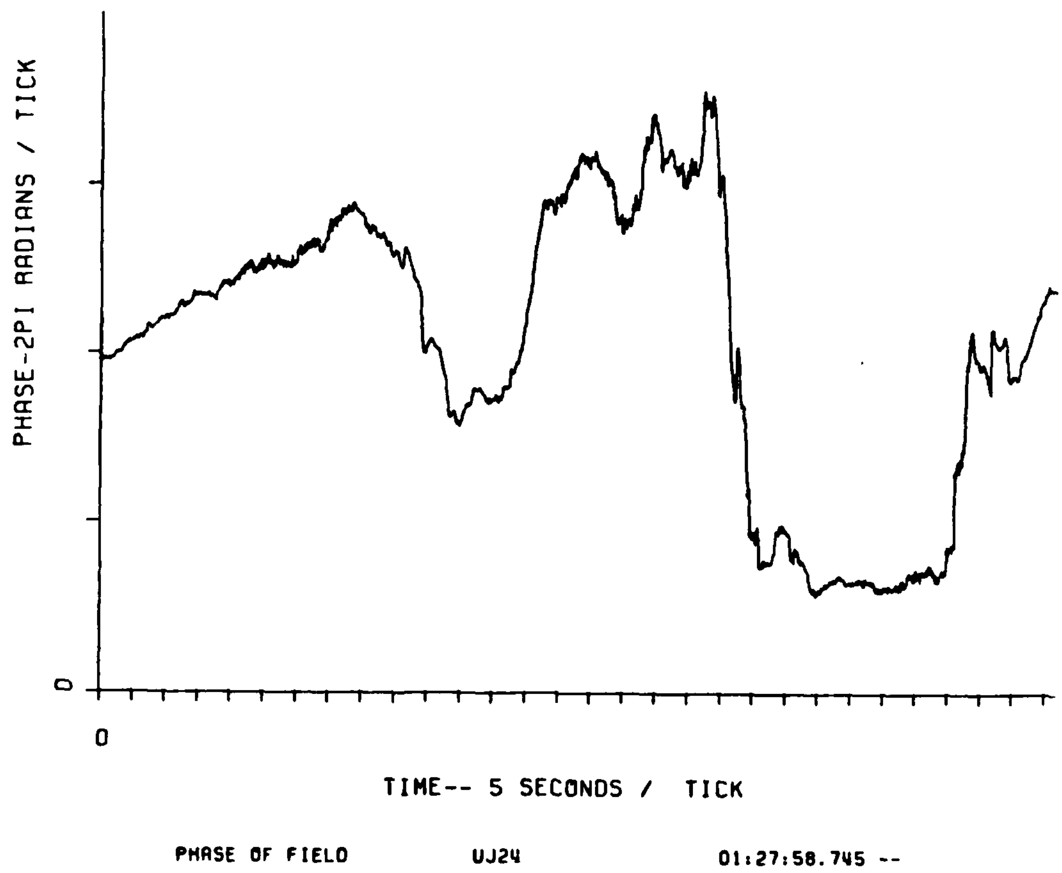

Figure 61. Uplink Phase Effects on JAN Pass 24, R+2^{h}15^m

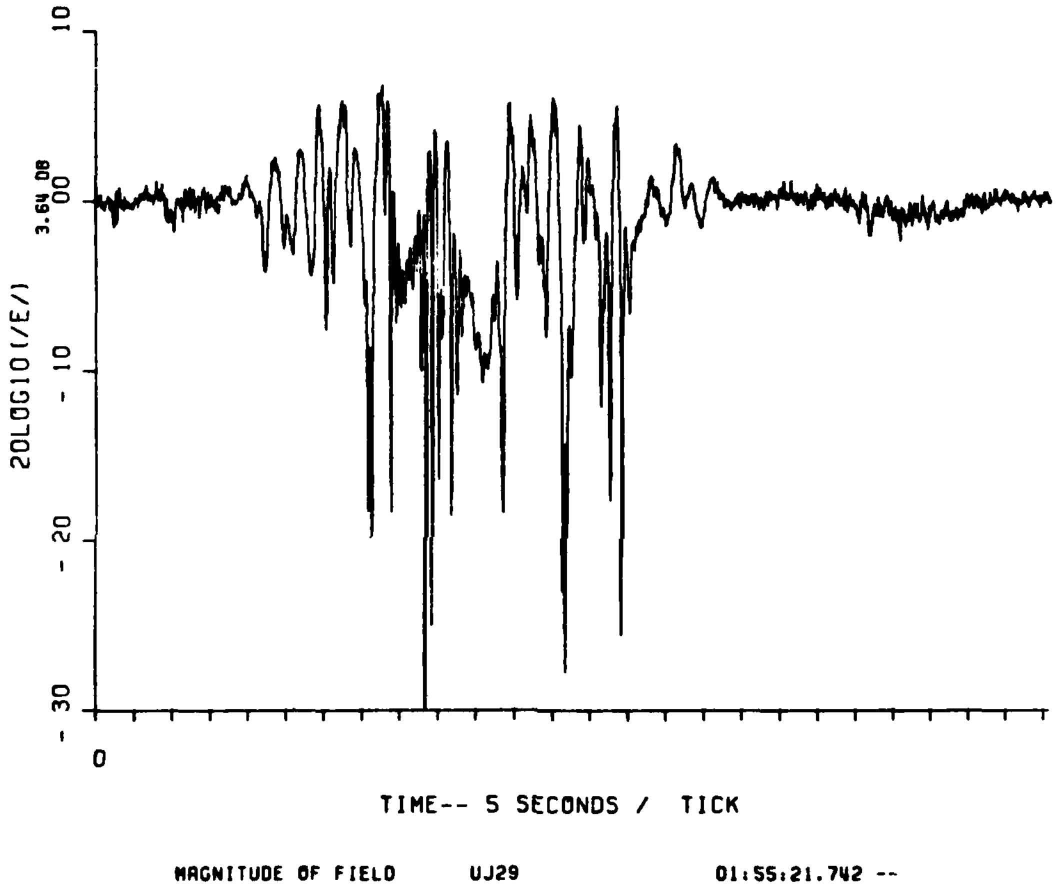

Figure 62. Uplink Fading on JAN Pass 29, $R+2^h43^m$

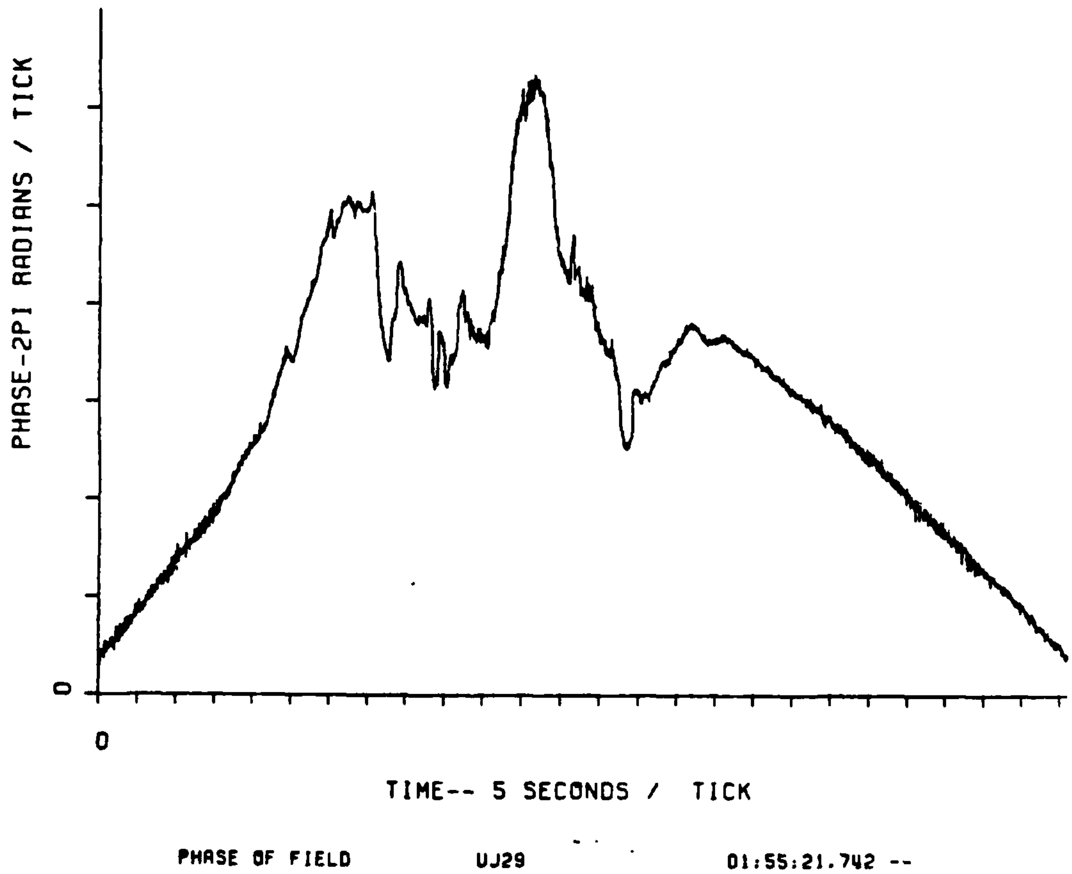

Figure 63. Uplink Phase Effects on JAN Pass 29, R+2^{h}43^m

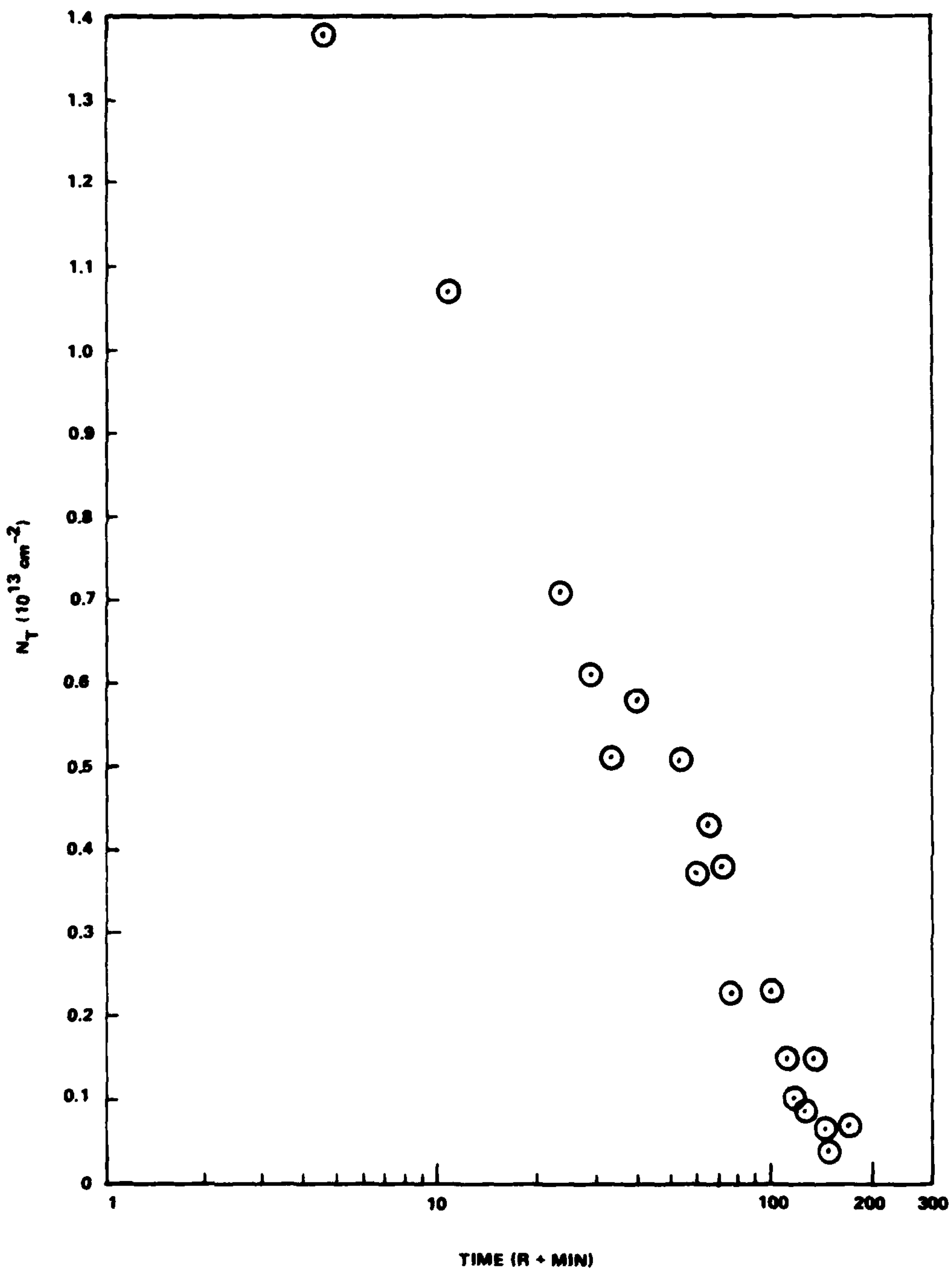

Figure 64. Integrated Electron Content Versus Time for JAN

SECTION VI

CONCLUSIONS

The PLACES Aircraft Experiment measured the propagation characteristics of the striated barium ion cloud using the LES-8 satellite in a manner similar to the STRESS experiment, The primary utility of this data is to provide information on striation evolution to late times that can aid theoretical developments. Additionally it provides an opportunity to work in a "hands on" real world situation with satellite communication systems, striated plasmas and propagation data that facilitate the physical interpretation of theoretical calculations/predictions. The downlink tone data obtained during PLACES is of higher quality than that obtained during the STRESS experiment of 1977 (Prettie et al, 1977). Only limited downlink data was available from STRESS due to conflicts with higher priority communications tests. The uplink tone data is believed to be of about the same quality.

The scintillation effects observed are similar to those observed during STRESS with the exception of the long deep defocusing seen at early times. During HOPE a -20 dB defocus lasted for approximately 75 seconds. From this it should be obvious that even large chunks of high density plasma ($\sim 10^7$ cm^{-3}) can be important to UHF satellite communication systems.

The IRIS cloud moved rapidly southeast and should therefore have resulted in a morphologically older cloud faster than seen before. Its data is also of interest around the beacon occultation time. JAN on the other hand moved slower than any oberved before. JAN should yield the highest quality data. Backpropagation processing of these signals to provide estimates of the integrated plasma content through the ion cloud striations is planned during subsequent processing. It is anticipated

that this data may be able to provide insight to current issues in striation phenomenology such as freezing. Freezing is a postulated late-time phenomenon wherein bifurcation stops and the striations move as a unit. The processing software and techniques for reducing the aircraft data were developed during the STRESS data reduction. This same software will be used during the PLACES data reduction.

SECTION VII

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